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SOUTHERN FOREST EXPERIMENT STATION

1968

U.S. FOREST SERVICE RESEARCH NOTE

SO-76

Forest Service, U.S. Dept. of Agriculture

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SOUTHEASTERN FOREST EXPERIMENT STATION

LONGLEAF PINE REGENERATION IN MOUNTAIN AND PIEDMONT PROVINCES OF ALABAMA

Thomas C. Croker, Jr.
SOUTHERN FOREST EXPERIMENT STATION

Excellent stands of Pinus palustris *Mill. can be established naturally under a shelterwood overstory during a good seed year. Seedbed burning greatly increases establishment and can be done without damage to the soil on steep slopes. Direct seeding is likely to fail where squirrel populations are high, and late sowing may be necessary to prevent loss from frost heaving. Brownspot infection varies greatly between sites, and burning for its control should not be done unless clearly needed.*

Longleaf pine forests grow on more than a million acres in the Mountain Valley and upper Piedmont provinces of north Alabama. Soil, climate, and topography are different here than in the Coastal Plain, and regeneration of the stands may require special measures. In the summer of 1961, a study [1] was installed to investigate several regeneration measures on four separate areas—two on the Talladega National Forest and two on the Kaul Trustee Forest.

PROCEDURE

The four areas were selected to represent typical regeneration problems.

On the Talladega National Forest, the Joseph Springs area near Anniston had an old-growth stand in which an improvement cut had just been completed. The remaining trees formed what was essentially a light shelterwood, averaging 26 square feet of basal area per acre. The site was a steep mountainside. There was a good cone crop, estimated to yield about 90,000 seeds per acre that fall. Most of the ground cover was undisturbed. For the study, the area was subdivided into two parts (locations) of about 6 acres each. At one location the natural seed crop was supplemented in November with 3 pounds per acre of seed coated with a bird and rodent repellent.[2] The aim was to assure a stand in case the natural crop failed to establish one. Scattered scrub hardwoods were injected with a herbicide in late summer. At each location seedbeds were

[1] The research was greatly aided by Hugh Kaul and Lewis Weaver of the Kaul Trustee Forest and by personnel of the Alabama National Forests.

[2] Derr, H. J., and Mann, W. F., Jr. Guidelines for direct-seeding longleaf pine. U.S. Dep. Agr. Forest Serv. Southern Forest Exp. Sta. Occas. Pap. 171, 22 pp. 1959.

burned on three randomly selected 1-acre plots, and three other plots were left unburned. Fires were set in September and were hot enough to scorch crowns of overstory trees considerably. About 20 percent of the trees died before the overstory was removed during the winter of 1964-65.

A similar test of natural regeneration was made on the Hollins area of the Kaul Forest near Goodwater, in the upper Piedmont. Slopes here were more moderate than at Joseph Springs, and disking with a tractor was feasible. Seedbed treatments—burning, burning and disking, and disking alone—were replicated three times in two locations in a completely randomized design with 18 plots. Plots were 1.7 acres in area. September burning caused very little damage to the overstory. Disking was done in October. The overstory was a little denser than at Joseph Springs, and seed was more plentiful: 29 square feet of basal area and 141,000 seeds per acre. A scattered stand of small scrub hardwoods was injected before seedbed treatment began, and the overstory was removed during the winter of 1962-63. One location was seeded supplementally in the same way as the Joseph Springs area.

Also on the Kaul Forest was the Bull Gap area. A scattered stand of scrub hardwoods, 4 to 8 inches d.b.h., dominated the site; practically no pine seed trees were present. Though the area was on a mountainside, slopes were moderate enough for tractor operations. Here, fall and winter sowings with a furrow seeder were tested on burned, burned-and-disked, and disked seedbeds. Three blocks were established in a split-plot design; the 18 plots were 0.5 acre in size. All hardwoods were injected and all seedbeds were prepared before the fall seeding was done in December 1961. The winter seeding was completed in March 1962. Sowing was at the rate of one sound seed per row foot. Since the seeder meandered to avoid obstructions, spacing between rows varied from 6 to 12 feet.

A fourth test was attempted on the Ivory Mountain area of the Talladega National Forest, near Heflin. The site and stand were like those at Bull Gap, and the same site-preparation treatments were applied. Squirrels, however, were very numerous and ate most of the seed from the initial sowings in December and March of 1961-62. When the attempt was repeated in 1962-63 squirrels again destroyed much of the seed; in addition, the winter was cold and many of the seedlings that did develop from the December sowing were killed by frost heaving. The formal trials at Ivory Mountain therefore were failures, but in 1964 three small areas were seeded to test whether squirrel control and late sowing would enable a stand to be established. Squirrels were hunted heavily in February, and seed was sown in early March on strips that had been disked the past September.

In each of the basic plots of the Joseph Springs, Hollins, and Bull Gap areas, 25 milacre subplots were mechanically established and examined in June 1962, November 1962, and November 1963 to determine establishment and survival of seedlings. Also, spots of treated and untreated seed were observed for several weeks after each sowing to identify predators. Differences in milacre stocking and trees per acre recorded during the last examination were tested for significance (0.05 level) by analysis of variance.

RESULTS

On the Joseph Springs area an excellent stand of reproduction was obtained on the burned plots, and growth was rapid (fig. 1). Many seedlings made height growth during the second year. On the final examination in November 1963, burned plots averaged more than 13,000 trees per acre, and 87 percent of the milacres were stocked. On the unburned plots the stand averaged 1,700 trees per acre and milacre stocking was 47 percent, significantly less than on burned plots. Differences in growth rate were not tested statistically, but were readily apparent on the ground. Supplemental seeding did not improve stocking.

The hot seedbed burn on the slopes caused no appreciable soil erosion or other detrimental effect. Very little brown spot infected the seedlings, and no burning was done for control.

At Hollins the stocking was good also. The stands averaged 86 percent milacre stocking and 13,000 trees per acre on burned plots, 90 percent and 19,000 trees on disked and burned plots, and 70 percent and 6,000 trees on disked plots. Treatment differences were significant

Figure 1.—*Longleaf pine seedlings on Joseph Springs area 4 years after the seedbed burn. A shelterwood overstory was removed 3 years after establishment of advance reproduction.*

for milacre stocking, nonsignificant for trees per acre. Growth here was much poorer than at Joseph Springs, probably because of a heavy and persistent infection of brown spot. A control burn was made, but the seedlings were rapidly reinfected from adjacent unburned and heavily diseased stands.

At Bull Gap, overall stocking was fairly good after two growing seasons. Averages for all treatments were 62 percent milacre stocking and 1,013 trees per acre. Neither seeding date nor seedbed preparation had an effect. In the relatively mild winter of 1961-62 there were no noticeable losses from frost heaving. Practically all seedlings made rapid height growth. Since there was very little brown spot, no burns were made. Growth here contrasted sharply with that at the Hollins plots a few miles away.

On the Ivory Mountain area, the observational seedings made during the third season were successful. Losses to squirrels were tolerable, and the lateness of the sowing avoided damage from frost heaving.

DISCUSSION

It was encouraging to find that excellent natural regeneration could be obtained in the Piedmont and Mountains under a shelterwood overstory with seedbed burning measures similar to those used in the Coastal Plain. There was no apparent damage to the soil, and the effect on seedling establishment and growth was about the same as in the Coastal Plain. The major problem was that of making a late summer burn on steep slopes without damaging the overstory excessively. Behavior of fire on mountain sites is quite different from that on the more gentle slopes of the Coastal Plain, and special firing techniques need to be developed. Disking the seedbed proved to be an unnecessary expense. The seed crops provided by the shelterwood trees were heavy enough so that losses to squirrels and other predators were tolerable.

Failure of direct seeding at Ivory Mountain clearly indicates that on cutover areas the forester should be alert to the twin dangers of squirrel predation and frost heaving. The success of March seeding combined with control of squirrels by hunting suggests a solution. Mann [3] now recommends March seeding for such areas. Effective squirrel repellents for longleaf seed would be very helpful.

Marked differences in brown-spot infection between regeneration areas suggest the need for research into basic causes. Meanwhile, the forester should carefully evaluate the need for brown-spot burns and not burn a regeneration area unless the need is clear.[4]

[3] Mann, W. F., Jr. Guides for direct-seeding the southern pines. Forest Farmer 25(7): 99-103. 1966.
[4] Croker, T. C., Jr. Crop-seedling method for planning brown-spot burns in longleaf pine. J. Forest. 65: 488. 1967.

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SPRAYING SOUTHERN PINES NOT PRACTICAL FOR TIP-MOTH CONTROL

Charles X Grano and Hoy C. Grigsby
SOUTHERN FOREST EXPERIMENT STATION

Planted loblolly, shortleaf, and shortleaf × slash hybrid pines chemically sprayed for 8 years were taller and had greater diameter than their unsprayed counterparts, but the cost of treatment was prohibitive.

Nantucket pine tip moths *(Rhyacionia frustrana* Comst.) often attack young loblolly *(Pinus taeda* L.) and shortleaf *(P. echinata* Mill.) pine stands, particularly plantations. An average of four broods per year are produced, necessitating repeated spraying to insure control *(1)*. Tip-moth attacks are seldom lethal, but severe infestations sometimes deform young trees and reduce their growth *(2, 3, 4, 5, 6)*. This note reports the effects of 8 years of tip-moth control on the growth of pines in a plantation in southern Arkansas.

Loblolly, shortleaf, and shortleaf × slash *(P. elliottii* Engelm. var. *elliottii)* hybrid pine [1] seedlings were outplanted in 1959 in Bradley County, Arkansas.[2] The shortleaf × slash hybrid was included in the test because of a suspected inherent resistance to tip moths. Three plots of each species measuring 81 by 63 feet and bearing 81 trees per plot were chemically sprayed, and an equal number of plots were untreated controls. Sufficient space was left between the treated plots and the controls to prevent contamination by drifting spray. The entire study area was protected from cattle and deer browsing.

With the exception of one soil application of granular phorate in April 1962, treatment consisted of spraying at approximately biweekly intervals from March through September, annually. A 2-percent DDT aqueous emulsion was sprayed for 7 of the 8 years. A combination of a 1-percent solution of benzene hexachloride and 1 pint of 50-percent malathion per 50-gallons of water was sprayed in 1966. Hand sprayers were used during the first 4 years. A John Bean power sprayer with a hand-held nozzle was used for the next 3 years, and a Boomjet nozzle attached to an 18-foot, vehicle-mounted boom, in the final year. Mist blowers will

[1] The shortleaf and shortleaf × slash hybrid stock was furnished by A. J. Hodges of Many, La.

[2] The study area is owned by the Bradley-Southern Division of Potlatch Forests, Inc.

probably be required in the future to reach the tops of the trees.

Trees were examined annually to determine how many were infested during each year.

The average annual rate of infestation was 11 percent for sprayed trees and 95 percent for the controls. After 8 years, sprayed trees averaged 3.5 feet (27 percent) taller than controls (table 1). The average diameter of treated trees was 0.7 inch (27 percent) greater than that of controls. All growth differences observed were statistically significant at the 0.05 level.

The tabular data for the shortleaf × slash hybrid mask an aberrant growth response unrelated to either tip-moth damage or chemical spray. About 16 percent of the hybrids in both the treated and control plots were abnormally stunted and deformed. This form of nanism has been observed in other shortleaf × slash hybrid tests in the South. Excluding the abnormal trees raises the average height of sprayed hybrids to 19.6 feet, making them taller than the two other species, and increases the average height of control hybrids to 13.5 feet. Growth differences between sprayed hybrid trees and their controls were greater than for the loblolly or shortleaf. Apparently, the hybrid is not unusually resistant to tip-moth damage.

Repeated spraying was effective against tip moths, but the cost was prohibitive. Such measures are justified only for experimental purposes and for the protection of highly valuable genetic stock. Even if two or three applications a year sufficed, the growth gain would scarcely compensate for the expenditure.

LITERATURE CITED

1. University of Arkansas.
   1960. Handbook on control of disease and insect pests attacking trees and shrubs in Arkansas. Agr. Ext. Serv. MP-59, 52 pp.
2. Afanasiev, Michel, and Ashdown, Donald.
   1951. The pine tip moth: how to recognize and control it. Okla. Agr. Exp. Sta., Okla. A&M Coll. Bull. B-377, 11 pp.
3. Beal, R. H.
   1967. Heavy tip moth attacks reduce early growth of loblolly and shortleaf pine. U. S. Dep. Agr. Forest Serv. Res. Note SO-54, 3 pp. Southern Forest Exp. Sta., New Orleans, La.
4. Foil, R. R., Merrifield, R. G., and Hansbrough, Thomas.
   1961. Results of the tip moth control on height growth of loblolly pine. La. State Univ., North La. Hill Farm Exp. Sta., Hill Farm Facts, Forest. II, 5 pp.
5. Wenger, K. F.
   1955. Height growth of loblolly pine seedlings in relation to seedling characteristics. Forest Sci. 1: 158-163.
6. Yates, H. O., III.
   1960. The Nantucket pine tip moth: a literature review. U. S. Dep. Agr. Forest Serv. Southeast. Forest Exp. Sta., Sta. Pap. 115, 19 pp.

Table 1.—*Tree size after 8 years of treatment*

Species	Average height		Average diameter	
	Sprayed	Control	Sprayed	Control
	– *Feet* –		– *Inches* –	
Loblolly	18.2	16.3	3.6	3.1
Shortleaf	13.9	11.0	2.6	2.1
Hybrid (shortleaf × slash)	17.9	12.3	3.6	2.5
All species	16.7	13.2	3.3	2.6

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CLIMATE AT THE SEED SOURCE AFFECTS LONGLEAF PINE PERFORMANCE IN LOUISIANA PLANTATION

Eugene Shoulders and Thomas A. Terry

SOUTHERN FOREST EXPERIMENT STATION

Survivals at 5 and 10 years were correlated with mean annual temperature at the seed source. Height growth was associated with early-season rainfall at the seed source.

To identify the geographic strain of a tree species that is best for planting in a given area, the local or regional performance of plants from throughout the species' range must be observed. This note reports 10-year results of a longleaf pine *(Pinus palustris* Mill.) source study in central Louisiana. Performances are given for plantings of longleaf series 4 and 6 of the Southwide Pine Seed Source Study *(8)*. Five-year results have been published *(5)*.

MATERIALS AND METHODS

Established on a cutover longleaf site in Rapides Parish in 1957, the plantings include 10 sources that cover most of the range of longleaf pine (fig. 1). Two sources are from Alabama, two are from Louisiana, and one each is from Virginia, South Carolina, Georgia, Florida, Mississippi, and Texas. Both the Appalachian Mountain and the Coastal Plain physiographic provinces are represented.

Series 4 samples the east-west distribution of the species; series 6 samples its north-south distribution. Local (Rapides Parish) and Georgia sources are in both series. The plantings are side by side in independent randomized block designs containing four replications each.

Mean annual temperatures at the sources range from 60° to 72° F.; annual rainfalls, from 46 to 62 inches. There is a spread of 11 inches in average early-season rainfall (January through April) and 13 inches in warm-season rainfall (April through September).

Soil of the planting site was derived from Coastal Plain deposits. It is deep, medium textured, and well drained. Annual rainfall averages 56 inches; 22 inches fall during January through April. Mean annual temperature is 67° F.

Trees were sprayed twice annually during the first 5 years with Bordeaux mixture to protect them against brown-spot needle blight,

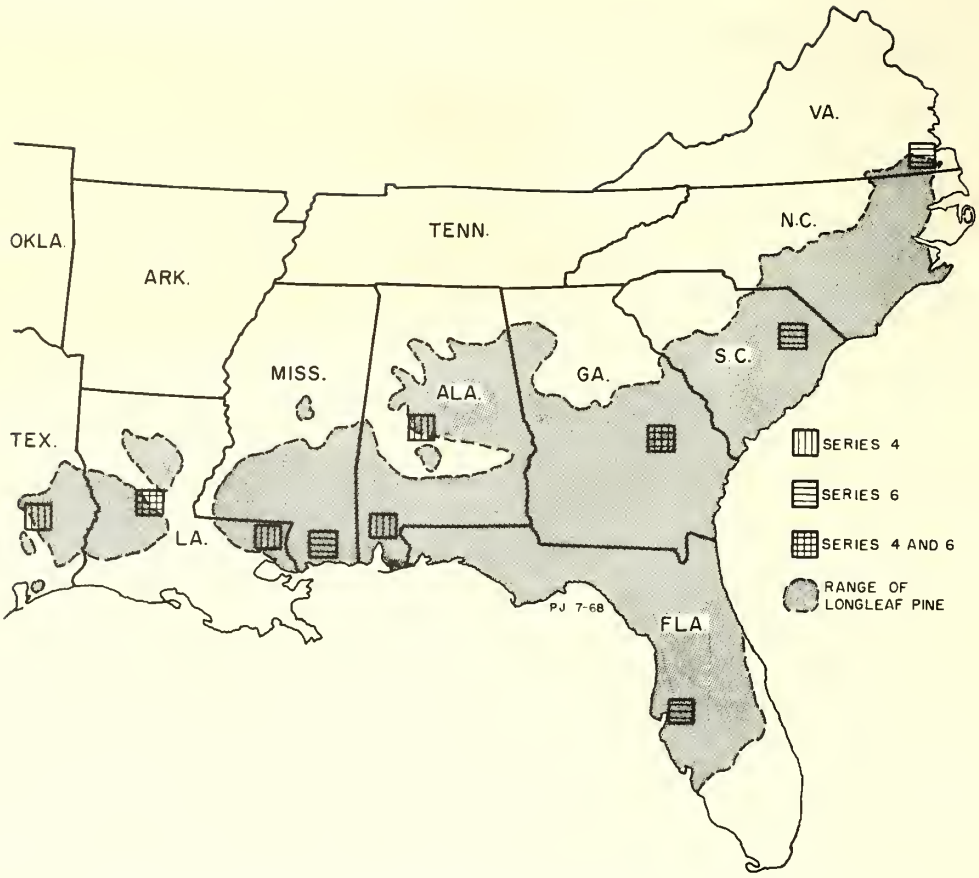

Figure 1.—*Range of longleaf pine and location of seed sources.*

which is caused by *Scirrhia acicola* (Dearn.) Siggers. Spraying reduced infection markedly, but did not eliminate the disease entirely.

Tenth-year results were analyzed for differences in survival, average height, and growth during the last 5 years. Seedlings less than 1.0 foot tall were omitted from growth analyses to minimize the impact on source performance of brown-spot needle blight and slow emergence from the grass stage.

The effects of seed origin on survival, height, and growth in both series were statistically significant.[1] In individual series, however, no prominent relationships were found between survival, height, or growth and climatic geologic, or geographic characteristics of the sources. To increase the size of sample for evaluations, the two series were analyzed jointly by the procedure of Gomes and Guimarães for combining experiments with common treatments *(2)*. Means that differed significantly were isolated with Duncan's multiple range test *(1, 3)*. Adjusted means were related to components of source climate by regression analyses.

[1] The 0.05 level of significance is reported throughout this note.

RESULTS AND DISCUSSION

Adjusted 10-year survivals ranged from 79 percent for the Perry County, Ala., source to 19 percent for the Hillsborough County, Fla., source. Seedlings from Perry County survived significantly better than those from Treutlen County, Ga.; Polk County, Tex.; Washington Parish, La.; and Hillsborough County, Fla. Florida trees were inferior to those from eight of the other nine sources. Trees from Rapides Parish survived as well as any others and significantly better than those from Georgia, Texas, Florida, and Washington Parish, La. Statistically significant differences are shown in the last column of table 1.

Table 1.—*Tenth-year survival of longleaf pine, adjusted for differences between series*

Seed source	Series	Mean annual temperature	Tenth-year survival
		°F.	Percent
Perry County, Ala.	4	64	79 [1]
Harrison County, Miss.	6	67	67
Rapides Parish, La.	4 & 6	67	65
Baldwin County, Ala.	4	67	64
Florence County, S. C.	6	64	63
Nansemond County, Va.	6	60	56
Treutlen County, Ga.	4 & 6	67	53
Polk County, Tex.	4	67	43
Washington Parish, La.	4	67	35
Hillsborough County, Fla.	6	72	19

[1] The difference between any two means not enclosed in the same brackets is statistically significant at 0.05 level.

Losses during the last 5 years reduced average survival by 12 percentage points, but only slightly changed relative performance of the seed sources.

Multiple regression analysis revealed a curvilinear relationship between survival and mean annual temperature of the source. The equation

$$Y = 48.145\ X - 0.38144\ X^2 - 1464.8,$$

where Y = adjusted arcsin $\sqrt{\text{percentage}}$ survival and X = mean annual temperature at the source, accounted for 63 percent (R = 0.79) of the variation in survival (fig. 2). The results support Wakeley's hypothesis *(8)* that temperature at the source influences planting survival. The curve culminated at 63° F., 4° lower than average for the planting site and local source and 3° higher than the minimum mean annual temperature represented in the test. Thus, it appears that movement of seed from a cooler to a warmer climate is safer for survival than movement from a warmer to a cooler climate. This interpretation is supported by results with other species, including some that have a much wider north-south range than longleaf pine *(6, 7, 10)*.

Trees from Baldwin County, Ala., were tallest and those from Hillsborough County, Fla., were shortest at age 10. Their adjusted average heights were 22.8 and 6.7 feet, respectively (table 2). Baldwin County trees were significantly taller than all others except those from Polk County, Tex. Conversely, Florida trees were equal in height only to Washington Parish, La., trees.

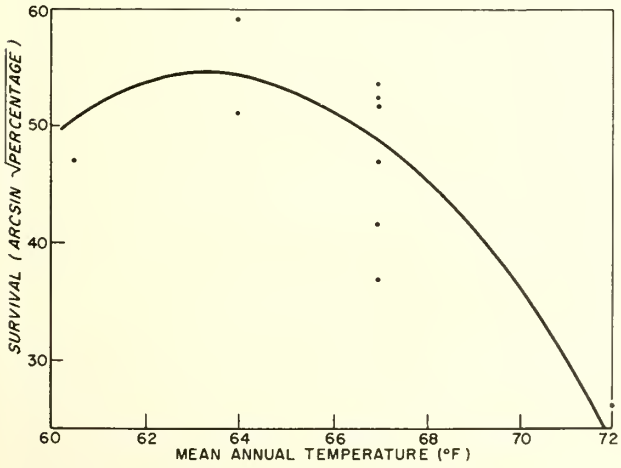

Figure 2.—*Relation between 10-year survival of longleaf pine seedlings and mean annual temperature at the seed source.*

Table 2.—*Tenth-year heights of longleaf pine, adjusted for differences between series*

Seed source	Series	Rainfall, January through April	Tenth-year height
		Inches	Feet
Baldwin County, Ala.	4	19	22.8 [1]
Polk County, Tex.	4	17	19.8
Perry County, Ala.	4	20	19.6
Harrison County, Miss.	6	20	18.0
Treutlen County, Ga.	4 & 6	15	14.6
Florence County, S. C.	6	13	14.4
Rapides Parish, La.	4 & 6	22	14.3
Nansemond County, Va.	6	14	14.1
Washington Parish, La.	4	22	8.5
Hillsborough County, Fla.	6	11	6.7

[1] The difference between any two means not enclosed in the same bracket is statistically significant at 0.05 level.

Trees from the local source averaged 14.3 feet tall. They were significantly shorter than representatives of Alabama, Texas, and Mississippi, but were taller than those from Florida and Washington Parish, La.

Heights were correlated with rainfall at the source. The relationship was best described by the equation

$$Y = 13.249\ X - 0.38079\ X^2 - 94.8,$$

where Y = average height (adjusted for differences between series) and X = January-through-April rainfall at the source (fig. 3). The equation accounted for 82 percent (R = 0.91) of the variation among source means. The curve culminates at 17.4 inches of early-season rainfall. Heights declined progressively

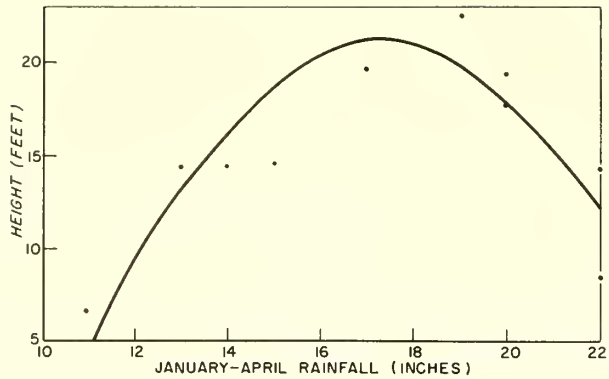

Figure 3.—*Tenth-year heights of longleaf pines in relation to early-season rainfall at the seed source.*

as rainfall at the source departed increasingly from the optimum of about 17 to 20 inches.

Periodic growth of trees that had emerged from the grass stage likewise was influenced by seed origin. The differences were smaller than in total height, however, and adjusted means ranged only from 18.4 feet for the Baldwin County, Ala., source to 13.6 feet for the Washington Parish, La., source (table 3). In the arrays in tables 2 and 3, sources do not occupy exactly the same positions, but the overall patterns are similar.

Table 3.—*Growth between ages 6 and 10 of longleaf pines that were 1 foot or more in height at age 5, adjusted for differences between series*

Seed source	Series	Five-year periodic growth
		Feet
Baldwin County, Ala.	4	18.4[1]
Harrison County, Miss.	6	17.1
Perry County, Ala.	4	16.5
Polk County, Tex.	4	16.3
Florence County, S. C.	6	15.5
Rapides Parish, La.	4 & 6	15.4
Treutlen County, Ga.	4 & 6	15.3
Hillsborough County, Fla.	6	14.7
Nansemond County, Va.	6	14.2
Washington Parish, La.	4	13.6

[1] The difference between any two means not enclosed in the same bracket is statistically significant at 0.05 level.

The multiple correlations coefficient between 5-year growth and early-season rainfall was 0.61. Probability of a larger coefficient due to chance is 0.20. Thus, early-season rainfall at the source appeared to be more closely associated with rapid emergence from the grass stage than with continued superior growth.

In several Mississippi seed source plantations, Henry and Wells *(4)* found that seedlings from the central Gulf Coast were less heavily infected with brown-spot than those from Texas, Louisiana, and Hillsborough County, Fla. The pattern of brown-spot resistance found by those authors agrees with trends in total heights reported here, except that trees of Texas origin were among the tallest in the present study, whereas they were among the most heavily diseased in Mississippi plantings.

The results suggest that early-season rainfall at the source has strongly influenced natural selection of longleaf pine. The pattern of correlation between rainfall and height supports Squillace and Kraus' *(7)* hypothesis that rapidly growing trees will predominate in areas where rainfall is optimum for growth, and that a race of superior growers should develop in these areas. The close agreement between height in this study and brown-spot resistance of the sources reported by Henry and Wells *(4)* indicates the possibility, at least, of an interrelationship among growth potential, disease resistance, and rainfall at the source.

Seed collection zones for longleaf pine cannot be delineated from results of a single planting. Nor, are 10-year heights completely reliable indicators of future growth *(9)*. It seems clear, nevertheless, that early growth of longleaf pine in central Louisiana would not be seriously reduced by substituting South Carolina, Georgia, or Texas seed for local seed, especially if measures were taken to insure high initial survival. Growth might be improved by importing seed from Alabama and Mississippi.

LITERATURE CITED

1. Duncan, D. B.
1955. Multiple range and multiple F tests. Biometrics 11: 1-42.

2. Gomes, F. P., and Guimarães, R. F.
1958. Joint analysis of experiments in complete randomized blocks with some common treatments. Biometrics 14: 521-526.

3. Harter, H. L.
1960. Critical values for Duncan's new multiple range test. Biometrics 16: 671-685.

4. Henry, B. W., and Wells, O. O.
1967. Variation in brown-spot infection of longleaf pine from several geographic sources. USDA Forest Serv. Res. Note SO-52, 4 pp. Southern Forest Exp. Sta., New Orleans, La.

5. Shoulders, Eugene.
1965. Seed origin affects longleaf pine in Louisiana plantation. USDA Forest Serv. Res. Note SO-19, 3 pp. Southern Forest Exp. Sta., New Orleans, La.

6. Squillace, A. E.
1966. Geographic variation in slash pine. Forest Sci. Monogr. 10, 56 pp.

7. Squillace, A. E., and Kraus, J. F.
1959. Early results of a seed source study of slash pine in Georgia and Florida. Fifth Southern Conf. on Forest Tree Impr. Proc. 1959: 21-34.

8. Wakeley, P. C.
1952. Working plan for cooperative study of geographic sources of southern pine seed. USDA Forest Serv. Southern Forest Expt. Sta. for the Comm. on Southern Forest Tree Impr., 35 pp.

9. Wakeley, P. C., and Bercaw, T. E.
1965. Loblolly pine provenance test at age 35. J. Forest. 63: 168-174.

10. Wells, O. O., and Wakeley, P. C.
1966. Geographic variation in survival, growth, fusiform-rust infection of planted loblolly pine. Forest Sci. Monogr. 11, 40 pp.

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ROOT GROWTH OF DIRECT-SEEDED SOUTHERN PINE SEEDLINGS

J. R. Jorgensen [1]

Root development of direct-seeded loblolly, longleaf, and slash pines was influenced by soil texture and structure during the first summer of growth. Plants in the field had root systems much different than reported for seedlings in greenhouses or nurseries.

In the research reported here, longleaf *(Pinus palustris* Mill.), loblolly *(P. taeda* L.), and slash *(P. elliottii* Engelm.) pines were direct-seeded to investigate the effects of soil texture on root development during the plants' first 5 months of growth. This span normally includes the most critical periods of a seedling's life, i. e., the first month, when the plant is becoming established; late spring and early summer, when root growth should be most rapid; and late summer, when droughts are likely to occur.

METHODS

In the spring of 1963 longleaf and slash pines were spot-sown on two undisturbed soils near Alexandria, in central Louisiana. The sowings were repeated the next spring, but with the addition of loblolly pine and a third soil. The three soils represented a wide range in texture and other properties. One was a droughty Lakeland loamy sand with a light growth of bunchgrass. The second soil, in the Susquehanna series, had a surface that varied with the degree of erosion from a compact clayey B horizon to a thin, sandy loam A horizon. Vegetation ranged from nothing where erosion had removed all or most of the A horizon to large clumps of bunchgrasses where much of the topsoil remained. The third soil, a Bowie sandy loam, was favorable for seedling development and growth but supported a heavy sod of perennial grasses. In this report the soils are referred to as sand, clay, and loam, respectively. Their physical properties are summarized in table 1.

After all sites had been cleared of woody vegetation, spots 1 foot square were scalped and sown with 15 to 20 seeds apiece. After the seedlings had become established, they were thinned to a maximum of five per spot. Re-establishment of grasses on the spots was prevented by spraying with a herbicide.

During 1963, seedlings were excavated approximately 30, 60, 100, and 150 days after

[1] Soil Scientist, Southeastern Forest Experiment Station, USDA Forest Service, Research Triangle Park, N. C.; formerly Soil Scientist, Southern Forest Experiment Station, Alexandria, La.

Table 1.—*Physical properties of selected soil horizons*

Soil type	Depth	Horizon	Soil texture	Mechanical analysis			Moisture-holding capacity	
				Sand	Silt	Clay	1/3 A	15 A
	Inches			*Percent*				
Lakeland loamy sand	1-4	A_1	Loamy sand	86	6	8	5.3	1.5
	24-28	C	Loamy sand	85	8	7	3.7	1.4
Susquehanna sandy loam	0-4	A	Sandy loam	58	30	12	9.3	3.6
	8-12	B_2	Clay	28	26	46	34.0	21.9
	24	C	Clay loam	35	26	39	25.6	15.7
Bowie sandy loam	0-4	A_1	Sandy loam	55	37	8	19.6	5.8
	11-15	B_{21}	Silt loam	34	52	14	17.5	6.1

germination, i. e., in late April or early May, June, July, and August. This schedule provided an initial excavation when plants first began to develop lateral roots and mycorrhizae, and later excavations when plants possessed root systems presumed to be characteristic of the species and soil. The same schedule was followed in 1964, except that the last lifting was in July.

Plants were removed from the sand with a stream of water from a small sprayer. Those growing in the loam were lifted with roots still embedded in a large block of soil, soaked overnight in a tub of water containing a water softener, and then washed free of earth. Clay-grown plants were dug by picking away the soil with a knife.

The proportion of lateral roots lost at any excavation probably was not high, but many succulent ends of taproots from plants on the loam and clay were broken and lost during the liftings at 100 and 150 days. In no case was breakage so severe as to obscure the root-growth patterns imposed by the soil.

Measurements included the cumulative lengths of all roots over ¼-inch long, taproot length, and number of lateral roots. Over the 2-year period the longleaf root measurements were from 101, 97, 66, and 37 seedlings excavated when 30, 60, 100, and 150 days old. For slash pine, 99, 72, 61, and 19 seedlings were excavated at the same ages. In the year loblolly was grown, 55, 66, and 35 plants were excavated at 30, 60, and 100 days of age. Number of plants varied with availability of manpower and seedlings.

It is not possible to say that the sample was unbiased. In the loam, a soil with abundant moisture early in the growing season, nearly every seed germinated, survival was high, and the plants were thinned by random selection. In the sand and clay germination was poor, many newly established plants died, and few spots required thinning. This mortality and low germination may have tended to eliminate plants that grew slowly at first or were less drought-resistant than the others.

LONGLEAF PINE

Longleaf plants developed rapidly on all sites in 1964 (table 2, fig. 1). When seedlings were 30 days old, taproots from the sand and loam averaged 5.4 inches long; those in the clay were about 2 inches shorter. Taproots grew regularly until at 100 days the average length was 11.5 inches. Plants lifted from the sand had taproots 2.2 inches longer than those from the clay; those from the loam were 1.8 inches shorter than those from the clay.

In 1963, taproots of 30-day-old seedlings grown on sand were about an inch shorter, and those from the clay an inch longer, than were obtained the following year. By the 100-day lifting, these taproots averaged 3.6 inches longer than those from comparable seedlings lifted a year later. Seedlings 150 days old in the sand and clay had taproots approximately 2 and 1.5 feet long, respectively.

Number of lateral roots and total length varied greatly with soil in 1964. Thirty-day-old plants from the clay had 23.2 inches of root, more than twice that possessed by seedlings from the sand. Those from the loam were intermediate. Lateral roots were fairly numerous, but plants from sand had less than half the number of those from clay.

In 1963 the 30- and 60-day plants had fewer and shorter roots than did seedlings the fol-

Table 2.—*Tap and total root length, and number of lateral roots on longleaf pine seedlings 30, 60, 100, and 150 days old, by soil and year*

Age (days)	Soil	Taproot length		Total root length		Lateral roots	
		1963	1964	1963	1964	1963	1964
		Inches				*Number*	
30	Sand	4.6	5.5	9.3	9.7	6.4	7.2
	Loam	..	5.4	..	15.6	.	12.2
	Clay	4.3	3.5	10.2	23.2	7.5	15.8
60	Sand	6.7	10.6	13.2	19.4	8.6	10.4
	Loam	..	6.8	..	28.2	..	16.6
	Clay	6.7	6.8	21.1	41.1	18.8	27.5
100	Sand	16.6	13.6	31.7	28.7	18.8	18.7
	Loam	..	9.6	..	53.3	..	36.3
	Clay	15.6	11.4	44.3	45.9	43.6	41.3
150	Sand	23.4	..	54.0	..	38.0	..
	Loam	..	..	..	..	..	..
	Clay	19.3	..	76.4	..	62.7	.

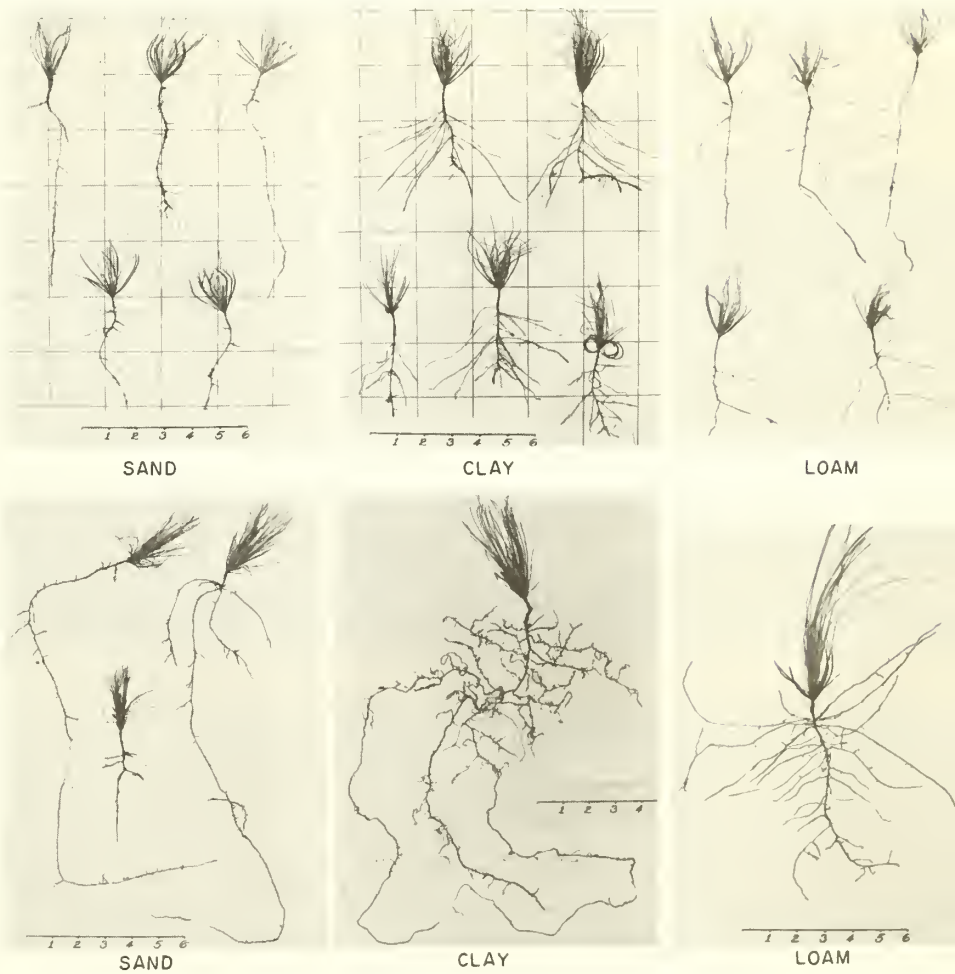

Figure 1.—*Longleaf pine seedlings grown in 1964 on sand, clay, and loam soils.* Top row: *seedlings when 30 days old.* Bottom row: *100 days old.*

lowing year, although the root development patterns, with respect to soil, were similar.

In both years, 100-day-old seedlings on the loam and clay soils had about 4 feet of root system, one-third more than that of stock from the sand. Number of lateral roots was also greatest on the loam and clay.

The last 1963 excavation, at 150 days, showed continued root growth, but seedlings in the sand were still about a third smaller, in total

length and number of lateral roots, than those from the clay.

SLASH PINE

In 1964, at the first lifting, taproots of slash pine seedlings were longest in the loam, shortest in the clay, and intermediate in the sand (table 3, fig. 2). At 60 and 100 days there was little soil influence on taproot length.

Taproots in 1963 tended to be longer and more affected by soil than those excavated a year later. At 100 days of age, sand and clay-

Table 3.—*Tap and total root length, and number of lateral roots on slash pine seedlings 30, 60, 100, and 150 days old, by soil and year*

Age (days)	Soil	Taproot length		Total root length		Lateral roots	
		1963	1964	1963	1964	1963	1964
		Inches				*Number*	
30	Sand	3.6	3.1	4.2	4.6	1.3	2.6
	Loam	...	4.5	...	10.2	...	8.9
	Clay	3.7	2.6	7.1	11.9	5.4	10.8
60	Sand	3.0	5.4	5.6	10.8	3.2	7.6
	Loam	...	5.6	...	16.6	...	12.6
	Clay	6.9	5.5	19.7	32.8	20.6	22.0
100	Sand	8.4	7.0	19.2	14.8	14.6	10.7
	Loam	...	6.4	...	22.2	...	18.6
	Clay	11.4	7.7	37.4	39.2	33.5	28.6
150	Sand	12.0	...	31.8	...	22.6	...
	Loam	...	...	...	...	...	...
	Clay	18.8	...	70.7	...	53.6	...

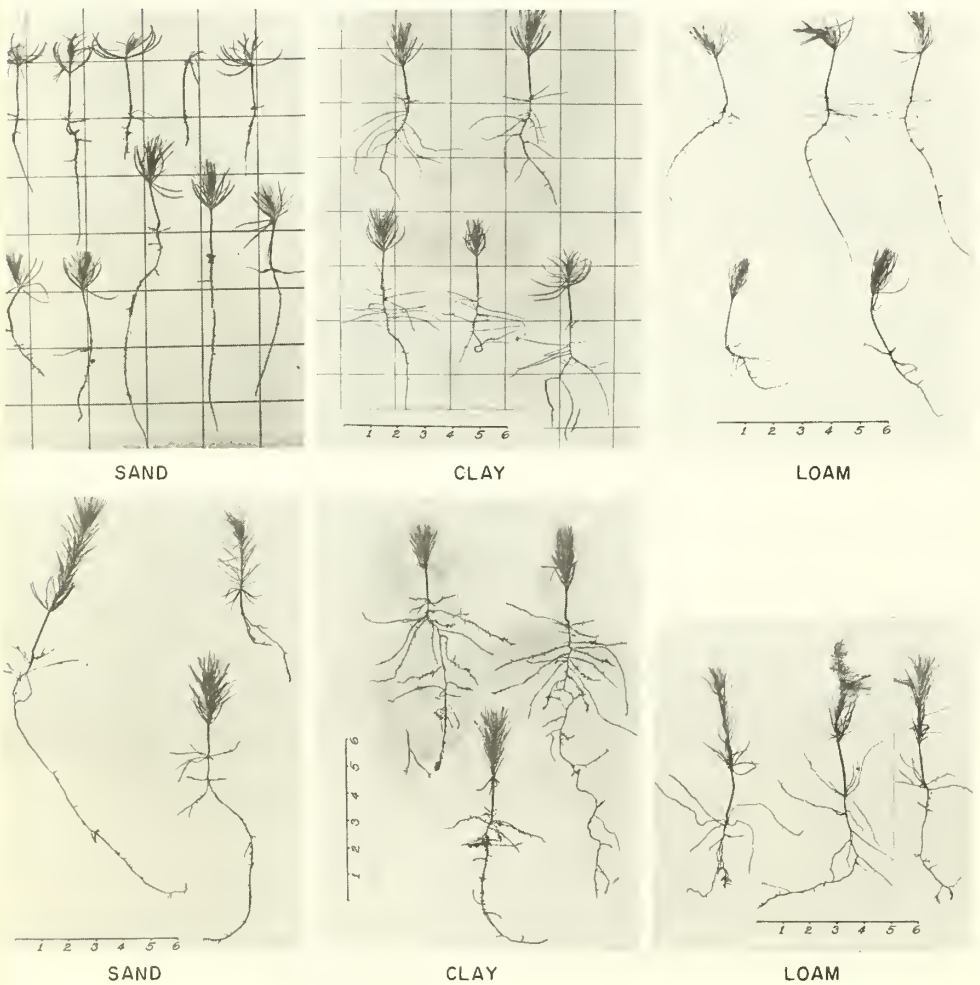

Figure 2.—*Slash pine seedlings at 30 days* (top row) *and 100 days* (bottom row).

grown plants had taproots extending 8.4 and 11.4 inches, respectively, or 1.4 and 3.7 inches longer than those of comparable plants lifted the following year.

Thirty-day-old plants from the sand had 4.6 inches of total root length and 2.6 lateral roots in 1964, less than half the length and number possessed by seedlings from the loam and clay. By 60 days of age roots of seedlings from the sand and clay had more than doubled in size, while those from the loam had grown by only about a third. Modest increases in total root length occurred between the 60- and 100-day liftings, but the relationship between the soil and the root systems was not altered.

At 30 and 60 days, roots were considerably fewer and shorter in 1963 than in 1964, but at 100 days plants from the 2 years were similar.

Roots grew rapidly from 100 to 150 days. Those of plants in the clay nearly doubled in size, while those in the sand increased about 50 percent.

LOBLOLLY PINE

Taproots of 30-day-old loblolly seedlings averaged 2.8 inches in sand and clay and 4.6 inches in loam (table 4, fig. 3). At 60 days there were no differences between soils, but

Table 4.—*Tap and total root length, and number of lateral roots in 1964 on loblolly pine seedlings 30, 60, and 100 day old, by soil*

Age (days)	Soil	Taproot length	Total root length	Lateral roots
		– *Inches* –		*Number*
30	Sand	2.8	3.2	0.8
	Loam	4.6	8.4	6.2
	Clay	2.9	7.9	7.5
60	Sand	6.3	10.6	5.9
	Loam	5.8	13.8	13.0
	Clay	5.6	15.3	12.7
100	Sand	7.7	13.0	10.7
	Loam	9.3	20.6	17.4
	Clay	10.2	21.5	20.0

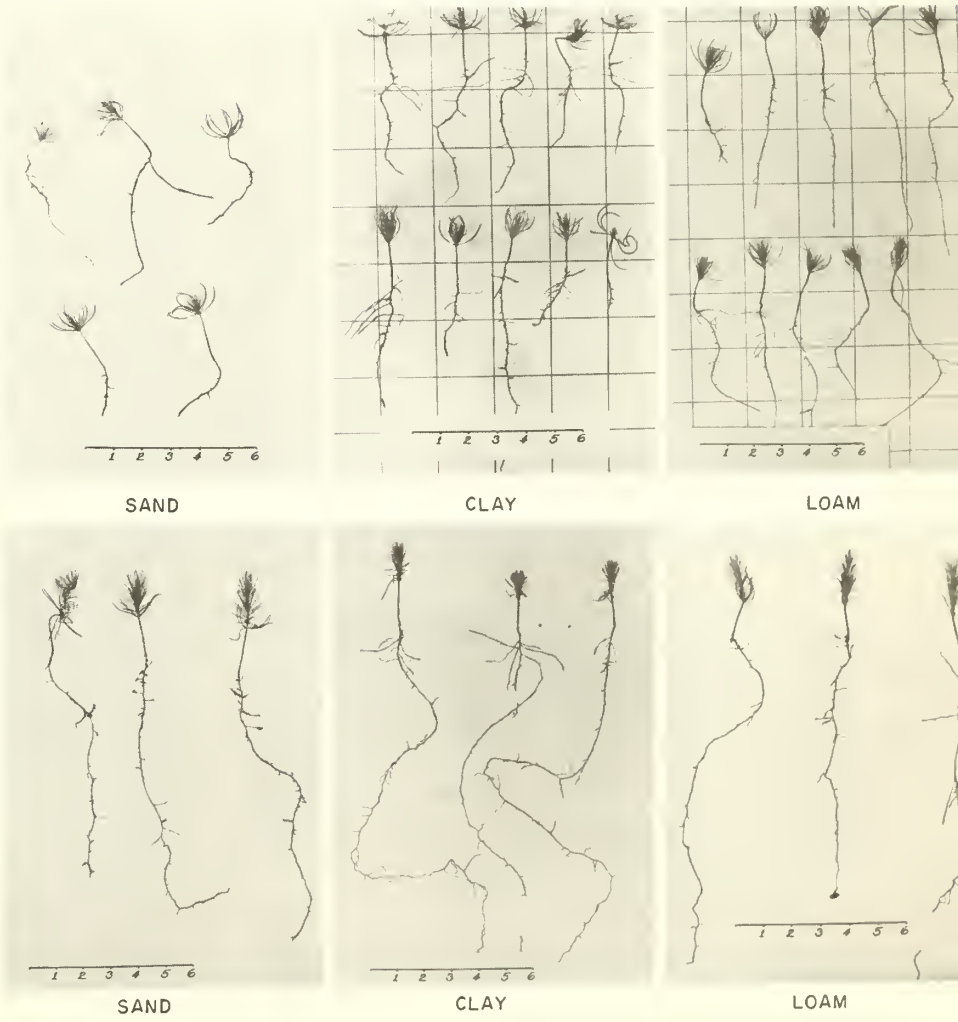

Figure 3.—
Loblolly pine seedlings at 30 days (top row) *and 100 days* (bottom row).

by 100 days taproots in clay had lengthened from 5.6 to 10.2 inches, while plants in sand had grown only 1.4 inches to a total of 7.7 inches. Seedlings from the loam were intermediate.

Total root length and numbers of lateral roots were strongly influenced by soil. The average 30-day-old plant from the sand had 3.2 inches of total root, less than half the 7.9 inches in the clay or 8.4 inches in the loam. Plants from the sand had few laterals, in contrast to an average of 6.8 for seedlings grown in loam or clay. By 60 days all root lengths nearly doubled, as did the number of roots on plants in the clay and loam. Seedlings from the sand now averaged 5.9 laterals per plant. Site influence continued at 100 days, with roots from the sand little more than half the length of those from the loam or clay.

OBSERVATIONS ON ALL SPECIES

Seedlings grown in the loam were well supplied with mycorrhizae at 30 days, while plants on the other two soils had relatively few mycorrhizal roots. By the time plants were 2 months old, all had some mycorrhizae.

Seedlings on the clay appeared to have more mycorrhizae than did those from the other two sites. The fungal association on this soil developed between peds and at times formed solid mycorrhizal mats, in contrast to the individual mycorrhizal short roots of plants on the other two sites. In many instances secondary roots and their mycorrhizal associates were flattened between the peds, since the dense, compact soil restricted growth to a plane. No mycorrhizae were found on roots in the plastic clay subsoil.

Soil moisture appeared to limit lateral root growth in the sand. Plants lifted during droughts did not have the white, succulent root tips characteristically associated with rapid elongation. These tips were found, however, when lifting coincided with periods of wet weather. Conversely, taproots in the sand usually showed continuous growth after they passed the depth where surface evaporation caused moisture fluctuation. In the clay and loam, white, rapidly elongating lateral root tips were found at each lifting.

Plants from the loam had plentiful moisture most of the year, and roots grew without regard to soil structure or time since rain. In the clay, water was concentrated by infiltration into joints between peds, and in these areas root growth was luxuriant. Only occasionally did roots penetrate into peds affected by surface drying. Veihmeyer and Hendrickson *(5)*, Taylor and Burnett *(4)*, and Edwards *et al. (1)* have also reported that plant roots have difficulty in penetrating dense soils.

DISCUSSION AND CONCLUSIONS

Root growth varied by both site and species. Though rainfall and soil moisture were not measured, weather differences in the 2-year period probably had some effect on number and length of roots. The pattern of site-influenced root development, however, remained the same in the 2 years.

In the greenhouse, Lenhart *(3)* grew 5-month-old longleaf pines with taproots 11.5 inches long in dry sand and 8.9 inches long in wet sand. These values are somewhat lower than the average of 15.1 inches obtained in the present study for field-grown plants 100 days old; they are about equal to the 9.6 inches reported here for loam soil. In clay, Lenhart's plants had taproots averaging 7.3 inches, as compared to 13.5 inches in this study. The differences may result from environmental variation between greenhouse and field.

Low moisture availability in the sand may account for the seedlings having few and short secondary roots but long primary roots, in contrast to the multiple laterals on plants from the finer soils. In Lenhart's work, watering at widely spaced intervals produced more rapid taproot development, but shorter laterals, than did frequent irrigation *(3)*.

Root systems of direct-seeded plants differed considerably from those of plants grown in the nursery, where water and nutrients are usually adequate. Taproots on 100-day-old seedlings were only about half the length of those measured by Huberman *(2)* in a nursery near Alexandria. The general form of the root system was also different. Nursery-grown longleaf usually have large taproots with few laterals. Slash and loblolly have small taproots but extensive laterals. In this study the longleaf root system was larger and had more laterals than did the loblolly and slash systems. Further-

more, in 1964 approximately 50 percent of the total root length of 100-day-old loblolly pines consisted of taproot, as compared to 30 percent for slash and longleaf seedlings. Possibly the extensive lateral development of longleaf is related to an inherent ability to utilize water. Longleaf is noted for its drought resistance and does well on many sites too dry for best growth of slash and loblolly.

LITERATURE CITED

1. Edwards, W. M., Fehrenbacher, J. B., and Vavra, J. P.
   1964. The effect of discrete ped density on corn root penetration in a planosol. Soil Sci. Soc. Amer. Proc. 28: 560-564.
2. Huberman, M. A.
   1940. Normal growth and development of southern pine seedlings in the nursery. Ecology 21: 323-334.
3. Lenhart, D. Y.
   1934. Initial root development of longleaf pine. J. Forest. 32: 459-461.
4. Taylor, H. M., and Burnett, E.
   1964. Influence of soil strength on the root-growth habits of plants. Soil Sci. 98: 174-180.
5. Veihmeyer, F. J., and Hendrickson, A. H.
   1948. Soil density and root penetration. Soil Sci. 65: 487-493.

SOUTHERN FOREST EXPERIMENT STATION

1968

U.S. FOREST SERVICE RESEARCH NOTE

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GRAPHIC ANALYSIS OF ERAMBERT'S HYBRID

R. C. Schmidtling and N. M. Scarbrough

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The variability of progeny in needle length, fascicle sheath length, and number of stomates per row per centimeter indicates that Erambert's hybrid is a cross between longleaf and loblolly, Sonderegger pine. The analysis described should help identify other southern pine hybrids.

Since it was discovered in Perry County, Mississippi, in 1949 and recognized as a hybrid by G. F. Erambert, the tree known as Erambert's hybrid has interested geneticists. Its progeny, which are highly variable in needle characteristics and growth rate, have been planted experimentally in Arkansas, Florida, Louisiana, Mississippi, and California.

Many of the seedlings from Erambert's hybrid resemble longleaf pine *(Pinus palustris* Mill.), which has always been thought to be one of the parent species. Others resemble loblolly pine *(P. taeda* L.) or something intermediate between longleaf and loblolly. A few of the progeny, however, appear to be most like slash pine *(P. elliottii* Engelm.). All three species occur in stands near Erambert's hybrid.

At the start of the present study, it seemed most likely that Erambert's hybrid was a cross between longleaf and loblolly—a Sonderegger pine. Critchfield *(3)* reported that Sonderegger pine, though difficult to produce experimentally, is fairly common in nature. Still, the possibility of slash pine parentage could not be ruled out prior to the graphic analysis shown here. Different flowering times usually prevent hybridization between longleaf and slash pine *(4)*, but putative natural hybrids have been reported *(5)*, and crosses have been produced experimentally *(3)*.

In the graphic method, variations among individual progeny in at least two characters are plotted for purebred trees, the tree in question, and any similar hybrids of known parentage. The characters chosen, taken together, must reliably differentiate among purebred trees of likely species. Since measurements must be made on the hybrid's progeny, results are most quickly obtained with characters that are faithfully expressed early in life.

A large number of such characters were measured in Erambert's hybrid and in Sonderegger, longleaf, loblolly, and slash pines in southern Mississippi. The most helpful proved to be fascicle sheath length, needle length, and

number of stomates per row per centimeter of needle.

The variations in these characters were determined for progeny resulting from wind pollination of Erambert's hybrid and seven Sonderegger pines. The values for progeny from the unknown hybrid were in the same range as, and no more variable than, those for progeny from the known hybrids (fig. 1).

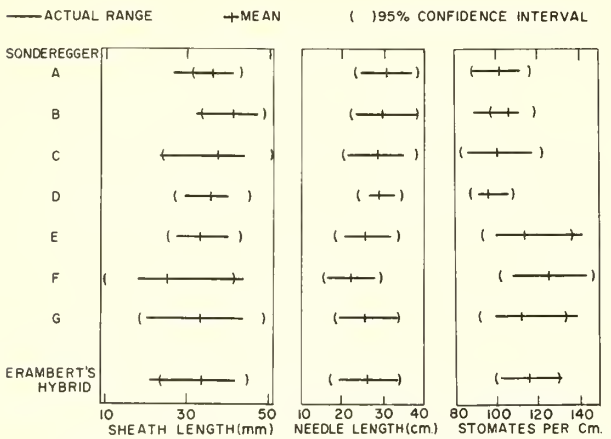

Figure 1.—*Variation in needle characters among progeny of seven Sonderegger pines and Erambert's hybrid.*

A scatter diagram was then prepared showing needle dimensions of longleaf, loblolly, slash, and Sonderegger pines, as well as Erambert's hybrid (fig. 2). The method of Anderson *(1)* was followed. The purebred trees of different species were clearly separated on the diagram. Both known hybrids and the unknown fell in a single area, that between longleaf and loblolly rather than longleaf and slash pine.

Controlled backcrosses were made between the hybrids and pure longleaf and loblolly pines. Progeny of both the known and the unknown hybrids had similar needle dimensions in crosses with pure species (fig. 3). In fact, the unknown hybrid's progeny were less like slash pine than were the progeny of some Sondereggers.

Erambert's hybrid and some of its progeny superficially resemble slash pine, but the same is true of many Sonderegger pines. The first Sondereggers identified were thought to be slash, even though the nearest known slash pines were several hundred miles distant *(2)*.

The results of the present study leave little doubt that Erambert's hybrid is a Sonderegger

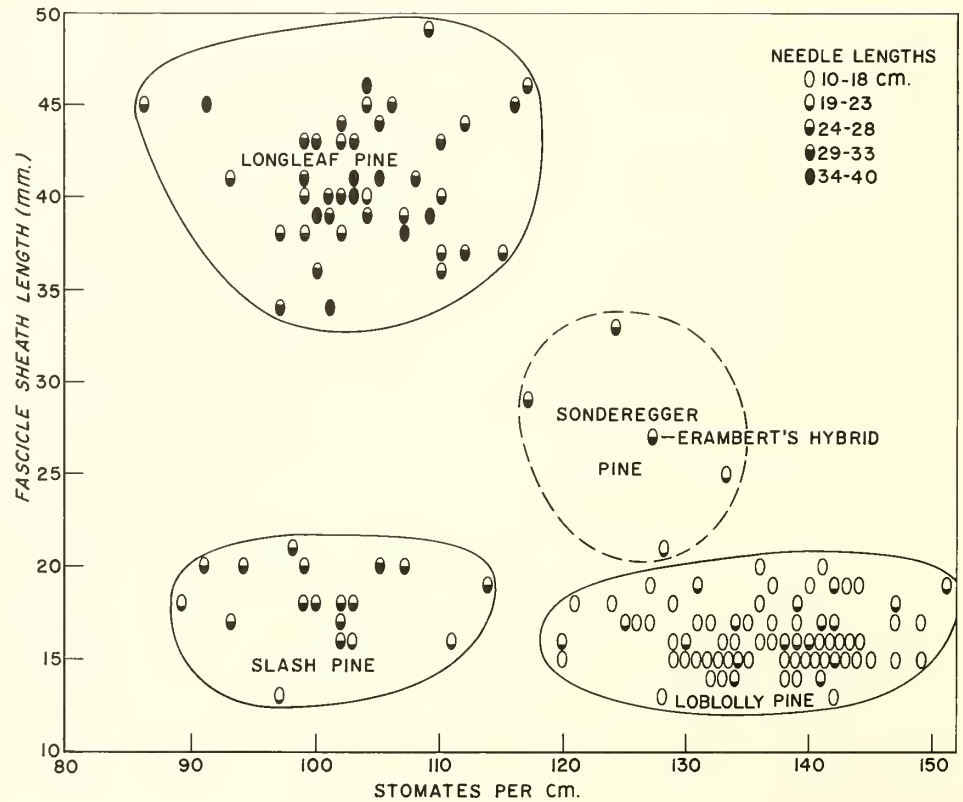

Figure 2.—*Scatter diagram for hybrids and pure species.*

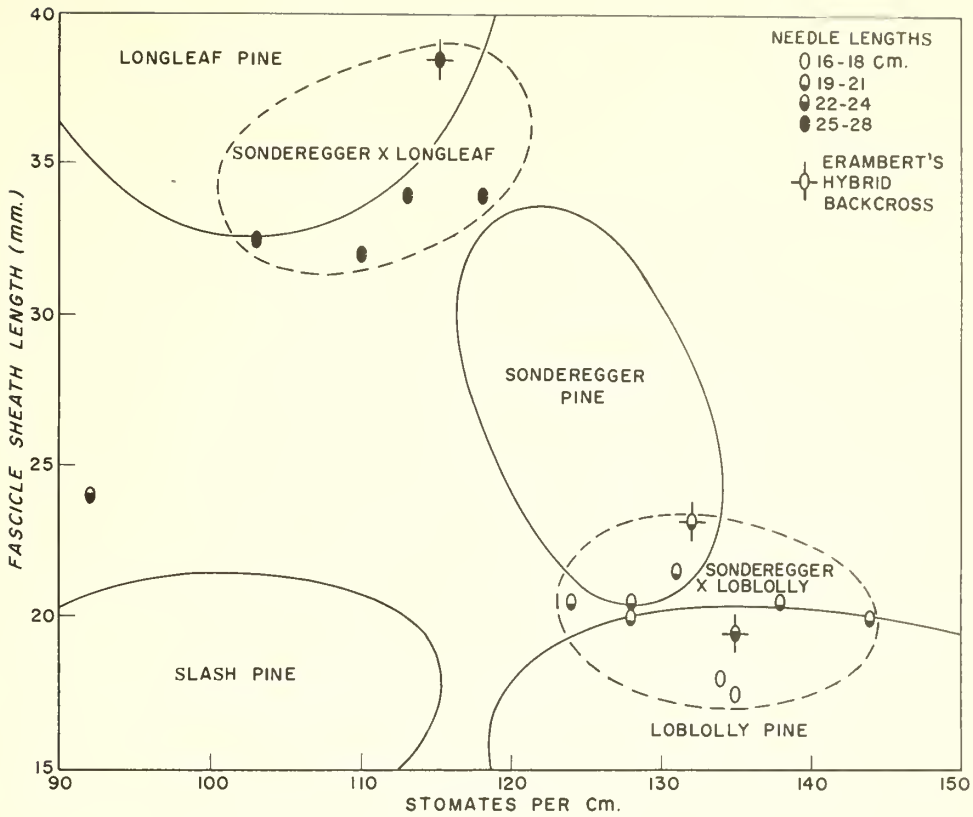

Figure 3.—
Scatter diagram for backcrosses. Circled areas are from figure 2.

pine. The method described should be helpful in identifying other southern pine hybrids.

LITERATURE CITED

1. Anderson, Edgar.
   1949. Introgressive hybridization. 190 pp. New York: John Wiley & Sons, Inc.
2. Chapman, H. H.
   1922. A new hybrid pine *(Pinus palustris* × *Pinus taeda)*. J. Forest. 20: 729-734.
3. Critchfield, W. B.
   1963. Hybridization of the southern pines in California. Forest Genet. Workshop Proc. 1962: 40-48. Macon, Ga.
4. Dorman, K. W., and Barber, J. C.
   1956. Time of flowering and seed ripening in southern pines. USDA Forest Serv. Southeast. Forest Exp. Sta., Sta. Pap. 72, 15 pp.
5. Mergen, F.
   1958. Genetic variation in needle characteristics of slash pine and in some of its hybrids. Silvae Genet. 7: 1-9.

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CLEARCUTTING AND PLANTING BEST FOR REGENERATING PINE IN NORTHERN MISSISSIPPI STUDY

Hamlin L. Williston [1]

Areas that had been clearcut of shortleaf and planted with loblolly pine were 58 percent stocked with dominant pines 10 years later. Satisfactory reproduction was not obtained after seed-tree, shelterwood, or selection cuttings. Board-foot growth (B) and cubic-foot growth (C) of residual trees during the 10 years after cutting were related to residual basal area (X) with the equations: $B = 5.26\ X + 18$ *and* $C = 0.73\ X + 2.2$.

More than three-fourths of the forest in northern Mississippi is on ridges and upper slopes, where pine produces more valuable crops in a shorter time than hardwoods. Managing shortleaf pine on these sites is difficult, because hardwood understories compete aggressively with young pines and produce a layer of litter that makes seedling establishment uncertain.

This note reports the 10-year results of a study designed to determine which of several types of harvest cutting and supplementary treatment produces the most desirable reproduction.

The study area is 17 miles northeast of Oxford, Mississippi, on the Tallahatchie Experimental Forest. Before treatment, it was occupied by 70- to 85-year-old shortleaf pines. Stands contained an average of 60 square feet of basal area and 10,000 board feet of sawtimber (International ¼-inch rule) per acre. There were no native loblolly pines in the area.

Most of the soil is Ruston, though Lexington is also common. Site indexes for shortleaf range from 75 to 85 feet (at age 50).

Mean annual rainfall is 52 inches. An average of 24 inches falls during the normal 218-day frost-free period.

METHODS

Treatments.—Forty-eight 2½-acre compartments were established in 1954. These compartments were grouped into three blocks,

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which were randomly assigned to be cut initially prior to the growing seasons of 1955, 1956, and 1957. One of eight treatments was randomly assigned to two compartments in each block. Subsequent developments required the merging of four treatments into two. Thus, of the six treatments described below, 2 and 3 are represented by 12 compartments, while the rest are represented by six.

1. Clearcut and plant loblolly pine on an 8- by 8-foot spacing. Previous studies *(3, 4)* had demonstrated that loblolly grew faster and survived as well as shortleaf in this area.

2. Cut all but eight to 10 pine seed trees, 12 inches d.b.h. or larger, per acre.

3. Cut all but the 25 best seed-producing pines per acre (shelterwood).

4. Extensive improvement selection with low basal area. Remove all merchantable hardwoods and enough pine to make an operable cut of at least 1,000 board feet per acre. Plant openings lacking natural pine reproduction with loblolly pine at a 12- by 12-foot spacing. Allow the growing stock to build up until 50 square feet of basal area per acre of pines 5 inches d.b.h. and larger can be left after an operable cut.

5. Intensive improvement selection with medium basal area. Cut as in treatment 4, but maintain a basal area of 65 square feet per acre in subsequent thinnings. Plant all openings lacking natural pine reproduction with loblolly pine at an 8- by 8-foot spacing.

6. Intensive improvement selection with high basal area. Cut and plant as in treatment 5, but maintain a basal area of 80 square feet per acre in subsequent thinnings.

Most of the hardwoods that interfered with pines were deadened after the initial cut. Planted pines that survived the first 4 years in the field were released from competing hardwoods.

Measurements.—A square 1-acre plot was established in the center of each 2½-acre compartment. Pole- and sawtimber-size trees (all trees 4.6 inches d.b.h. and larger) were inventoried on this acre prior to the initial cut and 5 and 10 years later. All saplings (trees 1.51 to 4.5 inches d.b.h.) were tallied on five 1/100-acre plots on each 1-acre plot during each inventory. Stocking percents for saplings are for this size of plot. All seedlings and sprouts 6 inches or taller and up to and including 1.5 inches d.b.h. were tallied by species on 20 milacre plots on each 1-acre plot. Seedling stocking is on a milacre basis. Combined stocking percents indicate the proportion of milacre plots occupied by pines of any size or dominated by pines larger than seedlings.

Pine cubic- and board-foot volume tables were constructed from data on logs in one block.

RESULTS

Pine regeneration.—The success of treatments is indicated by the number of young pines that have overcome the hardwood competition. The number of pine seedlings and saplings present in 1968 is shown in table 1. Pine stocking for all size classes is given in table 2. Only 155 shortleaf seedlings per acre were present prior to logging, and stocking averaged but 4 percent over the study area. In 1968, there were 267 pine seedlings per acre on the clearcut compartments, 526 on the seed-tree, 358 on the shelterwood, and 327 on the selection compartments. Seedling stocking percents for these four systems of cutting were 18, 30, 20, and 17.

Table 1.—*Seedlings and saplings per acre in 1968*

Treatment	Shortleaf		Loblolly	
	Free	Over-topped	Free	Over-topped
	– – – – *Number* – – – –			
Clearcut	100	258	175	25
Seed tree	142	476	. . .	. . .
Shelterwood	104	308	. . .	. . .
Selection—low basal area	33	208	25	16
Selection—medium basal area	8	242	83	33
Selection—high basal area	117	450	66	42

Very few pine saplings were on the study area before treatment. In 1968, there were 291 saplings per acre on the clearcut plots, 92 on the seed-tree, 54 on the shelterwood, and 114 on the selection compartments. Sapling stock-

Table 2.—*Pine stocking in 1968*

Treatment	Seedlings				Saplings				Occupied or dominated by pine, decreasing order of tree size				
	Shortleaf		Loblolly		Shortleaf		Loblolly		Pine sawtimber [1]	Pine poles	Pine saplings	Loblolly seedlings	Shortleaf seedlings
	Free	Overtopped	Free	Overtopped	Free	Overtopped	Free	Overtopped					
	Percent of area												
Clearcut	4	12	2	...	5	3	16	2	0	13	42	0	9
Seed tree	5	25	...	...	4	2	...	...	...	2	2	...	20
Shelterwood	6	14	...	...	2	1	...	...	...	4	3	...	16
Selection—low basal area	1	11	0	1	1	2	2	1	48	1	13	0	5
Selection—medium basal area	1	12	0	0	0	2	8	3	52	0	13	0	4
Selection—high basal area	3	20	1	2	2	2	4	2	62	6	7	1	2

[1] Seed trees and shelterwood trees ignored since they should be removed as soon as adequate reproduction is obtained.

ing percents for the four systems of cutting were 25, 4, 1, and 10.

Treatment has influenced the amount and stocking of pine seedlings surprisingly little. Normally one would expect to find the most pine seedlings on the seed-tree and shelterwood compartments, because these are the treatments specifically designed to obtain reproduction. In 1968, these compartments had fewer seedlings than the selection compartments whose openings were 34 percent stocked with pine seedlings. Seed-tree areas were 30 percent stocked, and shelterwood 15 percent. Only 6 percent of the clearcut area, 5 percent of the seed-tree, 6 percent of the shelterwood, and 2 percent of the selection area are occupied by pine seedlings that are not overtopped.

The failures of the seed-tree and shelterwood treatments must be attributed mainly to hardwood competition. Residual pines, averaging 14 to 16 inches d.b.h., were approximately 60 feet apart on the seed-tree areas and 30 to 36 feet apart on the shelterwood areas. Large seed crops were produced in 1957 and 1958, and, although seedlings were not counted, initial catches appeared to be adequate. Of course, had mineral soil been exposed, initial establishment would have been increased greatly—probably from three- to fivefold *(5)*.

Most of the seedlings established in 1957 and 1958 died. A low understory of young hardwoods, huckleberry bushes, blackberry briars, and muscadine vines will probably prevent further establishment of pine seedlings. Some overhead shade is desirable until seedlings become well established, but thereafter, shortleaf pine requires full sunlight to thrive *(1)*. Apparently, only those pine seedlings that got off to a good start shortly after logging were able to outstrip their hardwood competitors.

The clearcut treatment was best for pine regeneration. The clearcut areas are 64 percent stocked or dominated by pine seedlings, saplings, and poles (some of the planted loblolly is of pulpwood size). Stocking percentages on the other areas are 24 percent for the seed-tree, 23 percent for the shelterwood, and 37 percent for the selection areas. Only 8 percent of the seed-tree area, 6 percent of the shelterwood, and 16 percent of the openings on the selection compartments are stocked with or dominated by young pines that are free from competition, compared with 58 percent on the clearcut area.

Hardwood regeneration.—The numbers of small hardwoods prior to logging and 10 years later are given in table 3. During the first 5 years, the number of hardwood stems increased by 10 percent. During the second 5 years as stems increased in size, their numbers decreased by 22 percent, to 5,038 per acre. White oak, yellow-poplar, and sweetgum—the preferred species—make up less than 20 percent of the total. The young hardwood stand is not an attractive management alternative to pine.

Volume growth.—In the initial cut approximately 10,000 board feet per acre of pine were

Table 3.—*Hardwood seedlings and saplings*

Species	Prior to cutting	10 years after cutting
	Number per acre	
White oak	500	492
Post oak	775	453
Shumard & black oak	698	336
Other red oak	367	231
Blackjack oak	345	145
Hickory	847	690
Yellow-poplar	5	29
Sweetgum	286	280
Blackgum	1,161	1,025
Other species	1,450	1,357
Total	6,434	5,038

removed from the clearcut compartments, 8,000 from the seed-tree areas, 4,000 from the shelterwood compartments, and 1,300 from the selectively cut areas. The hardwood cut averaged 610 board feet per acre.

Stand and stocking development during the 10 years after treatment are summarized in table 4. Some very early mortality on the seed-tree and shelterwood plots was salvaged and added to the initial cut. During the 10 years, an average of one of the 10 seed trees per acre and two of the 25 shelterwood trees were killed by lightning, insects, and windthrow. Since the trees were large and represented a substantial proportion of the growing stock, their loss depressed the volume growth rate on the seed-tree and shelterwood plots. Some trees as large as 22 inches d.b.h. were left on the study plots. Probably, all trees larger than 18 inches d.b.h. should have been cut, because their rate of growth was too slow to justify the risk of loss.

Growth after treatment was related to residual basal area with the formulas:

$$C = 0.73\,X + 2.2 \qquad (r = 0.770)$$

where C = cubic-foot growth per acre and X = basal area, and

$$B = 5.26\,X + 18 \qquad (r = 0.783)$$

where B = board-foot growth and X = basal area.

Both correlations are statistically significant at the 0.01 level of confidence. Table 5 gives the computed annual growth during the 10 years after treatment for residual basal areas from 10 to 80 square feet per acre.

Table 5.—*Annual growth per acre during the 10 years after treatment*

Residual basal area (square feet per acre)	Annual growth	
	Cubic feet	*Board feet*
10	10	71
20	17	123
30	24	176
40	31	228
50	39	281
60	46	334
70	53	386
80	61	439

RECOMMENDATIONS

In northern Mississippi, as in many parts of the South, the rapid development of hardwood brush after logging is a serious problem. The results of the study reported here lead to

Table 4.—*Development of stand and stocking per acre during the 10 years after treatment*

Treatment	Pine after treatment				Pine 10 years later				Periodic annual volume growth	
	Trees	Basal area	Volume		Trees	Basal area	Volume			
	Number	*Sq. ft.*	*Cu. ft.*	*Bd. ft.*	*Number*	*Sq. ft.*	*Cu. ft.*	*Bd. ft.*	*Cu. ft.*	*Bd. ft.*
Clearcut	...	...	...	...	38.3	6	74	...	7	...
Seed tree	10.0	13	440	2,738	9.6	14	489	3,164	5	43
Shelterwood	23.4	26	851	5,220	22.5	30	1,052	6,788	20	157
Selection—low basal area	53.7	41	1,268	7,075	52.2	50	1,639	9,474	37	240
Selection—medium basal area	68.0	54	1,629	9,245	69.7	65	2,078	12,479	45	323
Selection—high basal area	95.2	65	1,868	9,923	94.0	75	2,368	13,381	50	346

two recommendations for managing shortleaf pine stands:

1. In stands with adequate yield, cut selectively as long as the growth rate holds up. If a good catch (1,000 or more per acre) of pine seedlings is obtained, release them from hardwood competition. Otherwise, do not worry about reproduction or go to any expense to obtain it. Half measures waste time and money. When the growth rate declines, treat as in 2.

2. Clearcut shortleaf sawtimber stands that are inadequately stocked or growing slowly. Where a fire will not cause excessive erosion, burn in the fall to reduce slash and brush. Immediately plant loblolly pine seedlings, and eliminate hardwood competition. Intensive hardwood control can increase height growth by as much as 5 feet in the first 5 years *(2)*.

LITERATURE CITED

1. Grano, C. X.
   1965. Shortleaf pine *(Pinus echinata* Mill.). *In* Silvics of forest trees of the United States, pp. 451-457. USDA Agr. Handbook 271.

2. Williston, H. L.
   1961. Intensive early release promotes growth of pines. Miss. Farm Res. 24(10): 5.

3. Williston, H. L.
   1962. Conifers for conversion planting in north Mississippi. USDA Forest Serv. Tree Planters' Notes 54, pp. 5-7.

4. Williston, H. L., and Huckenpahler, B. J.
   1958. Response of six conifers in north Mississippi underplantings. J. Forest. 56: 135-137.

5. Wood, O. M.
   1939. Reproduction of shortleaf pine following mechanical treatment of the seedbed. J. Forest. 37: 813-814.

SOUTHERN FOREST EXPERIMENT STATION

1968

U.S. FOREST SERVICE RESEARCH NOTE

SO-82

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THINNING IMPROVES GROWTH IN STAGNATED SWEETGUM STANDS

R. L. Johnson [1]

SOUTHERN FOREST EXPERIMENT STATION

Thinning in small (average d.b.h. 10 inches) but old sweetgum stands forestalled mortality and stimulated growth of some residuals. From a starting basal area of about 120 square feet per acre, selective thinning to approximately 70 square feet maximized cubic-foot growth over a 10-year period. Thinning to about 90 square feet gave equivalent total growth but the poorest growth rate per tree. Thinning to about 55 square feet gave the most growth per tree, but left too few trees to utilize the site fully.

Unlike many hardwoods, sweetgum *(Liquidambar styraciflua* L.) will survive on sites ranging from dry uplands where, at best, it reaches pulpwood size, to moist bottom lands where it is one of the most desirable commercial species. On many sites it occurs in very dense, almost pure, stands that tend to stagnate if not thinned. The degree of thinning or level of stocking that will maximize high-quality growth in pole-sized stands was sought in a recent study by the Southern Hardwoods Laboratory at Stoneville, Miss.

THE STUDY

The study site, consisting of 46 acres owned by the Chicago Mill and Lumber Company, is on the Tensas River south of Tallulah, La. The soil is Sharkey clay. Site index for sweetgum, estimated by Broadfoot's method, is 83 feet at 50 years *(2)*. Data obtained by sectioning a dominant tree indicated a site index of about 75 feet.

The sweetgums, about 75 years old, were probably of sprout origin and comprised about 80 percent of the stand. They appeared to have grown well (about 6½ inches) for the first 20 years, then poorly for the next 30 years—probably because of overstocking and stagnation. Perhaps as a result of some natural thinning, growth of a few trees again increased between 50 and 75 years (fig. 1).

[1] Stationed at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Miss., by the Southern Forest Experiment Station in cooperation with the Mississippi Agricultural Experiment Station and the Southern Hardwood Forest Research Group.

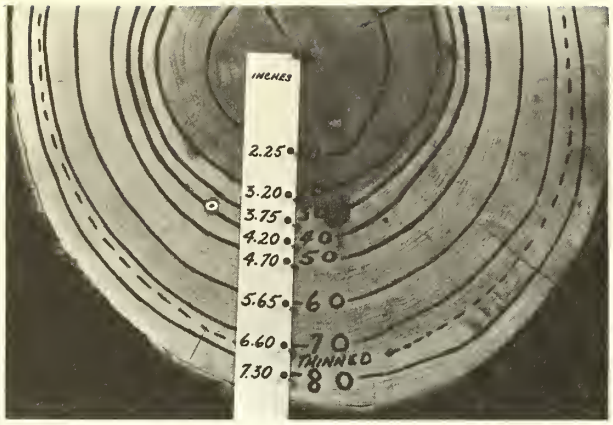

Figure 1.—*Cross section of codominant sweetgum, showing radial growth by 10-year periods.*

Water oaks *(Quercus nigra* L.), the next most common trees in the stand, were 10 to 15 years younger than the sweetgum but larger in diameter. Site index for water oak was about 80 feet at 50 years *(1)*.

The entire stand averaged 117.2 square feet of basal area and 3,018 cubic feet of volume per acre in 209 trees $\geq$ 5.0 inches d.b.h. (table 1).

THINNING TREATMENTS

Four treatments were applied in the winter of 1954-55 to plots measuring 5.5 by 7 chains. Each treatment was replicated three times in a randomized block design:

Check. No cutting. Average basal area about 120 square feet per acre.

Light thinning. Basal area reduced to about 90 square feet per acre.

Medium thinning. Basal area reduced to about 70 square feet.

Heavy thinning. Basal area reduced to about 55 square feet.

The order of priority for removing trees was: (a) those likely to die within 5 years, (b) those that were damaged or of poor form, (c) those of undesirable species, particularly boxelder and honeylocust, and (d) relatively desirable individuals whose removal improved spacing and was necessary to bring basal area to the intended level.

After thinning, all live trees at least 5.0 inches d.b.h. were measured at breast height and tagged on 1-acre interior plots of 2.5 by 4 chains. Diameters were retaken after 5 and 10 years. Local volume tables were developed from direct measurement of 100 felled trees and Abney measurement of 100 standing trees. Cubic-foot volumes were computed for merchantable wood up to a 4-inch top and board-foot volumes (Doyle) to a 12-inch top, both measured inside the bark.

GROWTH

About 15 percent of the trees on the check plots died between 1954 and 1964. On the other plots, mortality was less than 5 percent. Check plots, however, still averaged 1½ to 3 times as many trees in 1964 as the other treatments.

Diameter growth.—In 1954, the average sweetgum ranged from 10.3 inches d.b.h. on the check plots to 12.8 on the heavily thinned plots. Ten years later, the average was from 11.5 inches on the check to 14.6 on the heavily thinned plots. Based on the total number of survivors as shown in table 2, percentages of sweetgums growing more than 2 inches in diameter in 10 years were 5 in the check and 14, 22, and 38 in the light, medium, and heavy thinnings, respectively. Numbers of sweetgums growing at least 2 inches were 7 per acre in the check, 15 in the light thinning, and

Table 1.—*Residual stocking, basal area, and volumes per acre after the initial thinning and at end of the study*

Treatment	Trees		Basal area		Cubic volume		Sawtimber volume	
	1954	1964	1954	1964	1954	1964	1954	1964
	-- No. --		*-- Sq. ft. --*		*-- Cu. ft. --*		*-- Bd. ft. --*	
Check	209	178	119.9	131.6	3,097	3,586	1,550	3,932
Light thinning	125	120	87.6	108.3	2,338	3,071	896	2,898
Medium thinning	89	88	70.6	90.7	1,964	2,695	1,142	3,463
Heavy thinning	60	58	53.3	70.8	1,499	2,138	1,191	3,738

were the main reasons for classifying trees as "cut." Leave trees had few branches and generally well-developed, healthy crowns.

DISCUSSION AND CONCLUSIONS

Total growth within the life of this unmanaged stand has not been good. After 75 years both basal area and cubic volume were below the values shown by Winters and Osborne *(7)* and implied by Phillips *(4)* for sites of index 80. Tepper and Bamford *(6)* report that a sweetgum stand in the Northeast had half again as much cubic volume and basal area at half the age of this stand. According to Putnam, Furnival, and McKnight *(5)*, unmanaged free-growing trees on an average site should make nearly twice the diameter growth shown by the average tree in this stand.

Although it was obviously done late, thinning helped growth and development by eliminating trees that would otherwise have died or grown slowly and by stimulating growth of some residuals. The medium thinning, leaving about 70 square feet of basal area, appears best of those tested. Light thinning, leaving about 90 square feet, provided equivalent growth but scattered it over more trees. The heavy thinning, to 50 to 55 square feet, produced the best growth per tree, but the stand was too thin to utilize the site fully and hence growth per acre was low. Considerable epicormic branching also occurred in heavy thinning, thereby reducing bole quality. Experience and limited data indicate that similar stands should be rethinned to about 70 square feet before they exceed 110 square feet. The upper limit of basal area will depend somewhat on site quality, average diameter of the stand, and vigor of the dominant and codominant trees.

Although thinning is beneficial in pole-sized, stagnated stands such as described here, it may be difficult to decide at the onset whether to thin and continue to manage them, or to clearcut and start over. The decision may involve many factors, but managing the stand appears better for most owners. For example, with 30 years of management (two thinnings, one initially and one about 15 years later, plus a final clearcut) stands like these should produce nearly 11,500 board feet of sawtimber and about 30 cords of pulpwood per acre *(5)*. At stumpage values of $35 per M board feet and $3 per cord, which are more conservative than reported by McKnight *(3)*, the stand would yield about 5 percent compound interest (computed on the premanagement value as pulpwood). Extending the management period to about 60 years might double or triple the value of each 1,000 board feet, as trees would then be of veneer size and, presumably, quality.

LITERATURE CITED

1. Broadfoot, W. M.
   1963. Guide for evaluating water oak sites. USDA Forest Serv. Res. Pap. SO-1, 8 pp. Southern Forest Exp. Sta., New Orleans, La.

2. Broadfoot, W. M., and Krinard, R. M.
   1959. Guide for evaluating sweetgum sites. USDA Forest Serv. Southern Forest Exp. Sta. Occas. Pap. 176, 8 pp.

3. McKnight, J. S.
   1967. A new look at hardwood for pulping. Pulp and Pap. 41(14): 83-84.

4. Phillips, J. J.
   1961. Prediction of yield in old-field sweetgum stands in southern New Jersey. USDA Forest Serv. Northeast. Forest Exp. Sta. Res. Note 126, 4 pp.

5. Putnam, J. A., Furnival, G. M., and McKnight, J. S.
   1960. Management and inventory of southern hardwoods. USDA Agr. Handbook 181, 102 pp.

6. Tepper, H. B., and Bamford, G. T.
   1960. Thinning sweetgum stands in southern New Jersey. USDA Forest Serv. Northeast. Forest Exp. Sta. Res. Note 95, 3 pp.

7. Winters, R. K., and Osborne, J. G.
   1935. Growth and yield of second-growth red gum in fully stocked stands on alluvial lands in the South. USDA Forest Serv. Southern Forest Exp. Sta. Occas. Pap. 54, 12 pp.

With 1954 volumes taken as a base, annual cubic-foot growth averaged 1.6, 3.1, 3.7, and 4.3 percent simple interest for the check, light, medium, and heavy thinnings respectively. Comparable percentages for the sweetgum portion were 1.3, 2.8, 3.6, and 3.9.

Growth of sawtimber trees (at least 15.0 inches d.b.h.) ranged between 200 and 255 board feet per acre (Doyle) annually in all treatments, nearly 60 percent of which was ingrowth.

Survivor growth.—Survivor growth was calculated as the change in volume or basal area of live residual trees during the 10 years. Volume and basal area in trees that died during the period were subtracted from the 1954 after-treatment totals. As in the computation of gross growth, cull trees were assigned basal areas and volumes, and cordwood ingrowth trees were excluded.

Basal area growth of all survivors was best, 2.4 square feet per acre annually, on the lightly thinned plots. Cubic-foot growth also was slightly higher under light thinning, but still was equivalent to only about 1 cord per acre annually. The difference between cubic growth under light and heavy thinning was significant. With 1954 cubic volume in surviving original trees as a base, annual growth percent increased as degree of thinning increased (table 2).

Sawtimber survivors grew from 83 board feet per acre annually on the lightly thinned plots to 118 board feet on the heavily thinned plots. Sweetgum accounted for about one-fourth to one-half the growth, depending on treatment.

Cubic-foot growth per surviving tree, derived by dividing total survivor growth by the number of survivors, was highest—1.17 feet annually—in the heavily thinned plots (table 3). Trees given the medium thinning averaged 75 percent as much growth as the heavily thinned trees. Lightly thinned trees grew 60 percent as much as the heavily thinned trees, and check trees about 35 percent as much. Cubic-foot growth per tree was significantly higher under heavy thinning than in the check treatment.

Ingrowth.—Trees growing into cordwood size over the decade totaled 4 square feet of basal area for the medium and heavy thinnings, about 3 on lightly thinned plots, and about 1 on check plots. Ingrowing trees were short-bodied and added very little cubic volume to any treatments. Most of them were water oak and American elm.

Table 3.—*Annual growth*

Treatment	Basal area	Cordwood	Sawtimber
	Sq. ft.	*Cu. ft.*	*Bd. ft. (Doyle)*
	GROSS GROWTH PER ACRE		
Check	1.17	49	238
Light thinning	2.07	73	200
Medium thinning	2.00	73	232
Heavy thinning	1.75	64	255
	SURVIVOR GROWTH PER ACRE		
Check	2.21	72	104
Light thinning	2.40	84	83
Medium thinning	2.09	76	95
Heavy thinning	1.90	67	118
	SURVIVOR GROWTH PER TREE		
Check	0.012	0.41	9.4
Light thinning	.020	.68	11.8
Medium thinning	.024	.87	11.8
Heavy thinning	.033	1.17	11.8

EPICORMIC BRANCHING AND TREE QUALITY

To determine the degree to which thinning had stimulated epicormic branching, branches on the first 17.5 feet of each tree were counted in 1964. Although branch distribution is more important than branch number in determining tree quality, numbers in excess of five were considered "heavy" branching and did generally indicate low quality. About 40 percent of the heavily thinned trees had branched to this extent, as compared to 20 percent in all other treatments, including the check.

In 1964, nearly one-fifth of the sweetgum basal area on check plots was in trees judged worth retaining for another decade, if a second thinning were to be made. On plots given a light or medium thinning, about half the trees were classified as "leave." On heavily thinned plots the fraction was only one-fifth, chiefly because many trees had branched profusely. Other tree species combined had about the same proportion of leave trees in each treatment. Numerous epicormic branches, a suppressed or intermediate crown (usually associated with a below-average diameter), crown dieback, and boles damaged during thinning

Table 2.—*Stocking per acre and growth of surviving trees*

Treatment	Trees at least 5 inches d.b.h.				Trees at least 15.0 inches d.b.h.			
	Trees		Annual cubic-foot growth		Trees		Annual board-foot growth	
	Sweetgum	Others	Sweetgum	All	Sweetgum	Others	Sweetgum	All
	--No--		*--Pct.--*		*--No.--*		*--Pct.--*	
Check	141	37	2.2	2.5	6	5	7.9	7.1
Light thinning	106	14	3.3	3.6	3	4	7.7	10.2
Medium thinning	82	6	3.8	3.9	6	3	8.2	8.6
Heavy thinning	47	11	3.9	4.6	7	3	7.8	10.2

18 in both the medium and heavy thinnings. The greater frequency of fast growers in the more heavily thinned plots suggests that growth of some individual trees was stimulated; otherwise frequency of fast and slow growers would presumably have been the same on all plots. Of 1,130 measured sweetgums, only 19 grew 3 to 4 inches in diameter, two grew 4 to 5 inches, and one grew 5 to 6.

Nonsweetgums grew, on the average, 1.8 inches in diameter in 10 years on check plots, 3.5 under light thinning, 2.9 under medium thinning, and 3.5 under heavy thinning. Percentage and number of water oaks growing more than 2 inches in diameter in 10 years were 49 and eight in the check plots, 76 and five under light thinning, 54 and two under medium thinning, and 100 and six under heavy thinning. Of 100 surviving water oaks, 23 grew 3 to 4 inches in diameter in 10 years, 17 grew 4 to 5 inches, and eight grew 5 to 6 inches.

Gross growth.—Gross growth, as summarized in figure 2, is the total 10-year change in volume or basal area of the residual stand. Volumes in trees that died during the period were included in the totals for 1954, but not in those for 1964. The stand contained occasional cull trees, and these were assigned both volume and basal area, as if they were merchantable. Cordwood ingrowth, i. e., the volume in trees growing into cordwood size (5.0 inches d.b.h.) during the decade, was not included in gross growth.

Gross basal-area and cubic-foot growth were highest in the light and medium thinning, about 2 square feet and 0.9 cord (1 cord is equal to 80 cubic feet) per acre per year. Cubic-foot growth was significantly lower on the check plots than in each of the thinning treatments. (All statistical comparisons mentioned herein were made by Duncan's new multiple range test at the 95-percent level of probability.)

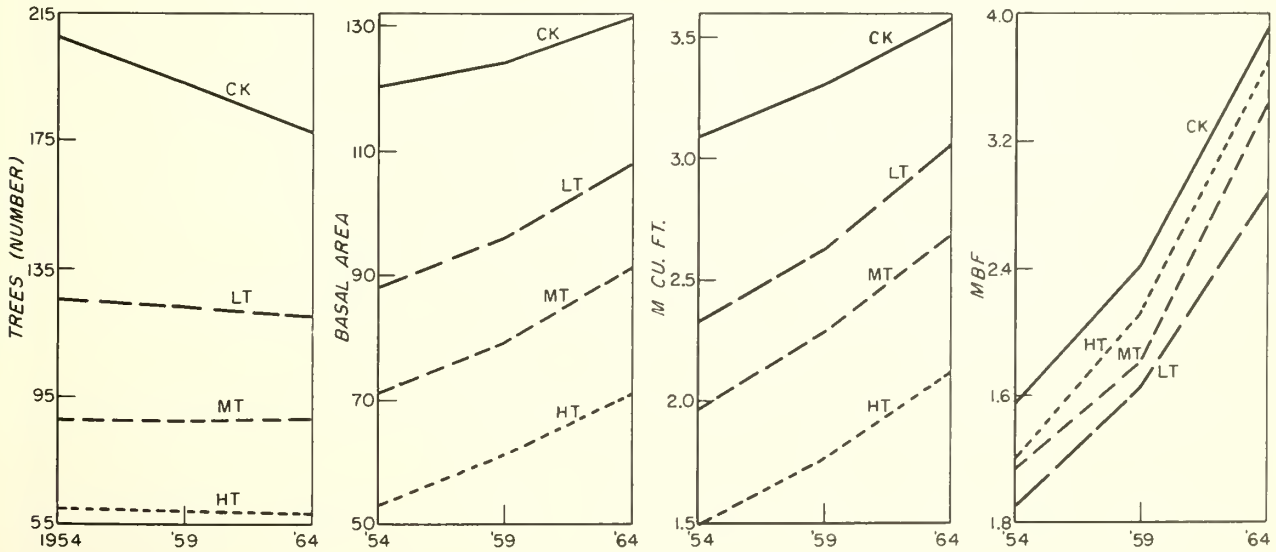

Figure 2.—*Number of trees, basal area, cubic-foot and board-foot volume per acre by treatment and years (gross data).*

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MOUNTAIN LONGLEAF PINE EXCELS ONLY IN LOCAL PLANTINGS

E. B. Snyder [1] and R. M. Allen [2]

SOUTHERN FOREST EXPERIMENT STATION

In reciprocal plantings of longleaf pine from the mountains of Alabama and the Gulf Coastal Plain in southern Mississippi, Alabama sources outperformed Mississippi sources only in the mountains.

Foresters have long surmised that longleaf pine *(Pinus palustris* Mill.) from seeds collected in the mountains of Alabama grows faster in early years than longleaf from elsewhere in the South. This note reports 10-year results of a study which compares the performance of mountain longleaf pine with that of a seed source in southern Mississippi. We briefly reported the methods and results of this study in a paper about breeding techniques *(6)*.

METHODS

Seeds were collected near Centreville, Bibb County (33° N. latitude 87° W. longitude), in central Alabama, and on the Harrison Experimental Forest near Saucier, Harrison County (30°30′ N. latitude 89° W. longitude), in southern Mississippi. The difference in elevation between the two sources is 600 feet. Mean annual temperature and rainfall are 64.2° F. and 55.2 inches in Centreville, and 66.5° F. and 71.6 inches in Saucier.

In each State, cones were collected from trees on a productive and an unproductive site. In the Alabama mountains the productive sites were in coves or on lower slopes, and the unproductive on dry ridges. In Mississippi the unproductive soil was sandier and drier than the productive soil.

In each of the four source areas, cones were collected from a single set of four trees in 1947, 1948, and 1949. In 1948, cones from two neighboring trees had to be collected to get a sufficient quantity on one area.

The seeds from all areas were sown in the Harrison Experimental Forest Nursery in Mississippi and the Alabama State Forest Nursery at Autaugaville. Seedlings were outplanted in

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the springs of 1949, 1950, and 1951, approximately 1½ years after cone collection. The plantings were on good and poor sites near the areas where seeds had been obtained. Mississippi sites were burned just prior to planting in 1949; Alabama sites were not burned.

On each of the four sites, 24 treatments (two geographic sources × two edaphic sources × 3 years × two nurseries) were replicated six times. One year's planting, which included eight combinations of treatments, constituted a whole plot. Thus, there were three outplantings, one for each year, on each of the four edaphic sites. A treatment subplot was a row of 25 trees which were planted at a 4- by 4-foot spacing. The 0.05 level of confidence was selected for the statistical analyses.

RESULTS

Edaphic source.—Trees from the productive seed source in Alabama (coves) grew significantly faster than trees from the unproductive Alabama source (ridges). The heights of progeny from the productive source excelled in nine of 12 outplantings. They failed only on poor sites, where brown-spot needle blight was most prevalent. Survival was higher for trees from the productive source in six of the eight outplantings in 1949 and 1950, but was significantly worse in 1951, a year of severe brown-spot attack. In all plantings combined, average-tree volume (d^2h) was 11 percent greater in progeny from the productive than from the unproductive source.

A comparison of Mississippi edaphic sources was not made, nor was the productive source included in geographic comparisons. We concluded from previous analyses *(6)* that productive source trees were closely grouped, semi-isolated from outside pollen, and probably inbred. Progeny from them contained only 69 percent of the volume of those from the unproductive source in Mississippi.

Nursery and planting site.—When data for all seed sources were pooled, seedlings from the Alabama nursery had higher 10-year survival in 11 of the 12 outplantings than seedlings from the Mississippi nursery. The average difference in survival was 44 percent. At age 10 the Alabama-grown stock's volume exceeded that of Mississippi stock by 64 percent. This was in spite of a tendency for Alabama stock to be smaller and more brown-spot susceptible. The survival differences were significant in 10 of the 12 outplantings.

There were no appreciable differences between heights on good and poor sites in 1949 and 1950 plantings. In 1951 plantings the poor sites produced 33-percent shorter trees than the good sites. The appearance of a difference between sites in the third planting year is attributable to a change in rainfall and a progressive buildup of brown spot *(6)* (fig. 1).

Survival was lower on poor than on good sites in all three planting years.

Geographic source.—First-year mortality was slightly less among trees from the Alabama

Figure 1.—
All the longleaf pine seedlings shown are from the same seed source. The 4-year-old seedlings at left are only 1 year younger than those at right. Stunting was caused by progressive buildup of brown spot on the planting area.

source than among those from the Mississippi source in most 1949 and 1950 plantings; it was considerably less in the 1951 plantings (fig. 2). Mortality between the first and 10th years, however, was higher for trees from Alabama sources. Thus, 10-year survival was higher for Mississippi trees. Much of the late mortality of Alabama progeny was caused by brown spot, which infected 17 percent more of the foliage of mountain that coastal longleaf. The difference in infection rate was statistically significant.

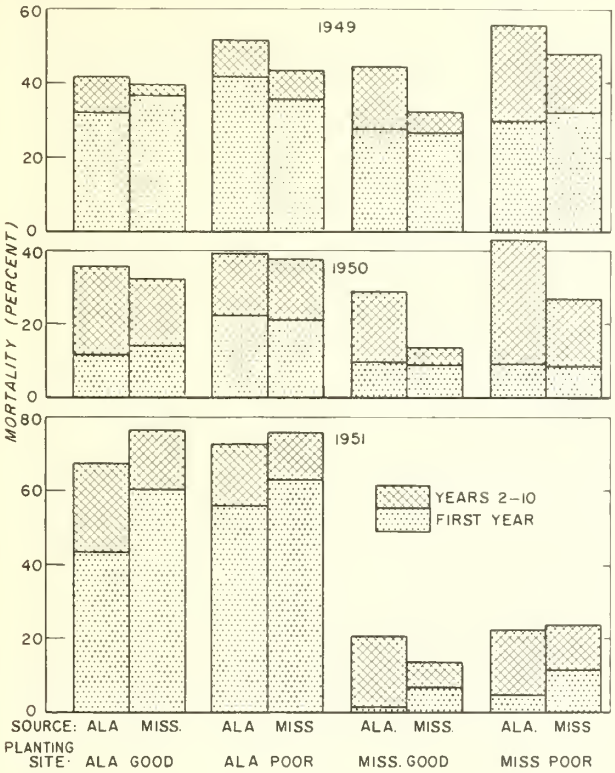

Figure 2.—*Mortality in plantings, by seed source.*

A summary of data by State shows that trees grew fastest near their own seed sources:

Planted in	Source	
	Alabama	Mississippi
	Height in feet	
Alabama (3,600 trees)	15.9	15.2
Mississippi (1,800 trees)	14.6	15.6

The 10-year volume advantages for local sources were 15 percent in Alabama and 19 percent in Mississippi. Apparently, seeds from the Alabama source should be planted in central Alabama, and the Mississippi seed should be planted in Mississippi.

DISCUSSION

Because of the small number of female parents sampled, the results of the present study, by themselves, cannot be considered conclusive. Similar comparisons of performance of mountain longleaf and coastal longleaf have been made in plantings in several States. The results are summarized in table 1. In five of

Table 1.—*Coastal compared to mountain longleaf performance*

Character	Publication	Age	Place tested	Performance of coastal compared to mountain source
Height and survival	Shoulders *(4)*	5 years or less	Louisiana	–
Do.	Texas Forest Service *(7)*	do.	Texas	–
Do.	Harms [1]	do.	Georgia	+
Nursery stem and root growth	Snyder *(5)*	do.	Mississippi	O
Height and survival	Collins *(2)*	10 years	Georgia	+
Do.	Texas Forest Service *(8)*	do.	Texas	+
Brown spot	Bethune and Roth *(1)*	5 years or less	Georgia	+
Do.	Henry and Wells *(3)*	do.	Mississippi and Louisiana	O
Height and survival	Wells and Wakeley *(10)*	10 years	Southern half of range	+ [2]

[1] W. R. Harms, furnished unpublished data from the USDA Forest Serv., Southeast. Forest Exp. Sta., Macon, Ga. Planter 15 in Dooly County and Planter 55 in Wilcox County, Southwide Pine Seed Source Study, longleaf series 4 and longleaf series 6. 1962.

[2] Except western Louisiana, Texas, and northern Alabama.

the nine experiments, coastal longleaf outperformed mountain longleaf. The Alabama source was superior in two plantings, one in Louisiana and one in Texas.

The faster growth of coastal longleaf when planted locally in the present study appeared to be caused by superior resistance to brown-spot needle blight. Since Alabama is in the lightly attacked zone and Mississippi is heavily attacked *(9)*, a difference in resistance would not be surprising. Henry and Wells *(3)*, however, did not find such a difference in Mississippi and Louisiana plantings. Additional information on geographic differences in disease prevalence, disease impact on growth, and genetic resistance will be needed to fully assess differences in performance by seed source.

It is clear, however, that for the conditions under which longleaf pine is normally planted, the mountains of Alabama are not a universally superior source of seeds. In fact, very recent results *(10)* indicate that the Bibb County elevation of 650 feet in the present study may be the lowest at which mountain longleaf can be advantageously planted.

LITERATURE CITED

1. Bethune, J. E., and Roth, E. R.
   1960. Source of seed affects growth of longleaf pine—fifth year results. USDA Forest Serv. Southeast. Forest Exp. Sta. Res. Notes 146, 2 pp.
2. Collins, A. B., III.
   1964. Longleaf pine seed source planting in Georgia—tenth year results. USDA Forest Serv. Res. Note SE-19, 3 pp. Southeast. Forest Exp. Sta., Asheville, N. C.
3. Henry, B. W., and Wells, O. O.
   1967. Variation in brown-spot infection of longleaf pine from several geographic sources. USDA Forest Serv. Res. Note SO-52, 4 pp. Southern Forest Exp. Sta., New Orleans, La.
4. Shoulders, Eugene.
   1965. Seed origin affects longleaf pine in Louisiana plantation. USDA Forest Serv. Res. Note SO-19, 3 pp. Southern Forest Exp. Sta., New Orleans, La.
5. Snyder, E. B.
   1961. Racial variation in root form of longleaf pine seedlings. Sixth Southern Conf. on Forest Tree Impr. Proc. 1961: 53-59, 64a.
6. Snyder, E. B., and Allen, R. M.
   1963. Sampling, nursery, and year-replication effects in a longleaf pine progeny test. Forest Genet. Workshop Proc. 1962: 26-27. Southern Forest Tree Impr. Comm. and Soc. Amer. Forest. Tree Impr. Comm.
7. Texas Forest Service.
   1962. Tenth progress report of the cooperative forest tree improvement program. Tex. Forest Serv. Circ. 77, 18 pp.
8. Texas Forest Service.
   1964. Twelfth progress report of the cooperative forest tree improvement program. Tex. Forest Serv. Circ. 89, 8 pp.
9. Wakeley, P. C.
   1954. Planting the southern pines. USDA Agr. Monogr. 18, 233 pp.
10. Wells, O. O., and Wakeley, P. C.
   1969. Variation in longleaf pine from several geographic sources. Forest Sci. (In press)

SOUTHERN FOREST EXPERIMENT STATION

1968

U.S. FOREST SERVICE RESEARCH NOTE

SO-84

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REVISED CALCULATOR FOR BARR AND STROUD DENDROMETERS

Clement Mesavage [1]

With pasted-on scales, a slide rule can be used to field-check readings made with all models of Barr and Stroud dendrometers.

Since the Barr and Stroud dendrometer is not a direct-reading instrument, several types of aids have been developed for quick checks of distance, height, and stem diameters. Experience with these indicates that a slide rule, suggested by Grosenbaugh *(2)* and constructed by Bruce *(1)*, is the most effective alternative at this time. The experimental prototype is not durable enough for constant field use, however, nor is it graduated to accommodate the new model FP-15 Barr and Stroud dendrometer. This model has a vertical swing that extends beyond that provided by the present slide rule, and its inclinometer is graduated in terms of 1 + sine and 1 — sine, rather than in terms of sine alone.

The author collaborated with Bruce to design and construct scales that will more nearly meet field requirements and accommodate all Barr and Stroud models now in use. Like its predecessor, the new rule was prepared by modifying Grosenbaugh's BCLEX program *(2*, p. 47) so that an IBM 7040 computer would print out logarithms of slant range, diameter, and appropriate functions of T and F grad. The instrument parameters were changed to agree with recent revisions of the STX computer program *(3)*. These logarithms, and logarithms of cosines needed to compute horizontal distances, were plotted on scales about 36 inches long, then reduced for attachment to standard double-faced 10- or 5-inch slide rules. Printed on thin paper that is weather- and rub-resistant, the scales can be affixed to rule surfaces with rubber cement, and can be positioned for hairline accuracy. Sets, illustrated in figure 1, are available on request from the Southern Forest Experiment Station.

Scales labeled AA, AB, AC, and AD are attached to one side of a slide rule, and are used to convert T grad (the first setting) to slant distance and to calculate height and hor-

[1] The author is Forester, Division of Timber Management, National Forest System, USDA Forest Service. The slide-rule scales described here were devised largely while he was on the staff of the Southern Forest Experiment Station, USDA Forest Service, at Harrison, Arkansas.

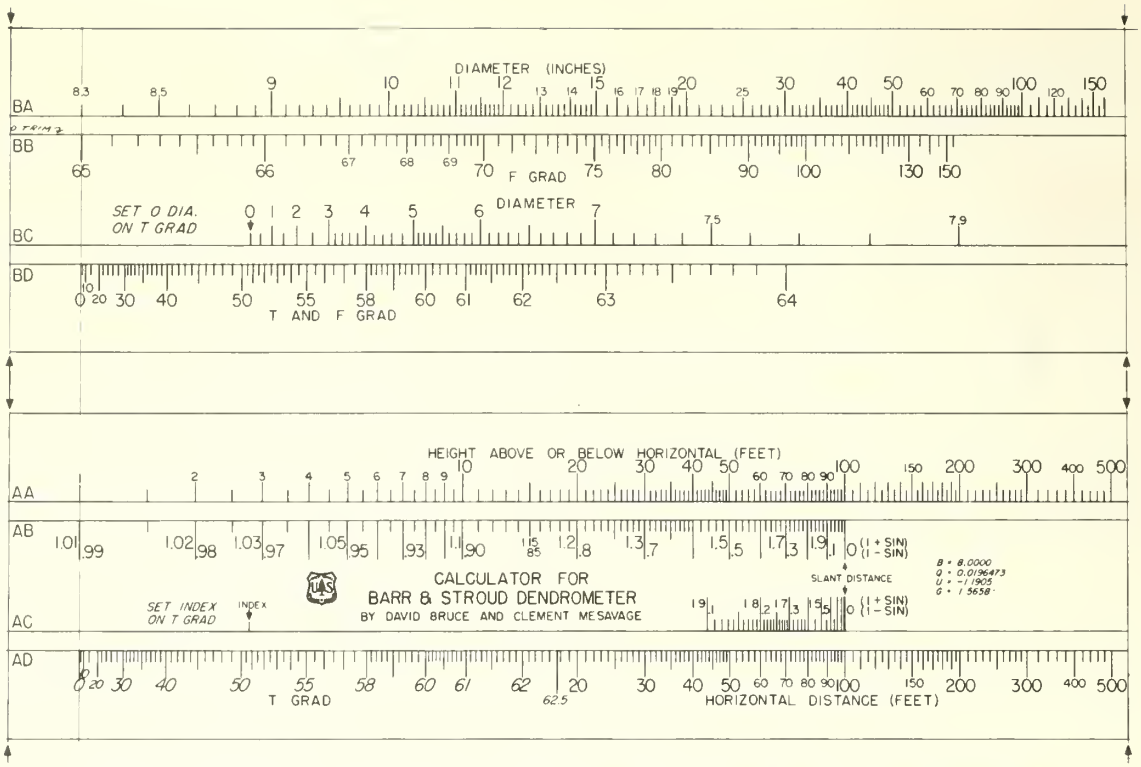

Figure 1.—*Scales for adapting a 5-inch double-face slide rule as a calculator for Barr and Stroud dendrometers.*

izontal distance for any elevation or depression of the line of sight. For example, the index on the AC scale shown by figure 1 is opposite a scale AD setting indicating a T grad of about 50.8. Slant distance is then read as 100 feet on scale AA opposite 0 on the AB scale. With a tilt of 40°, model FP-15 would show inclinometer readings of 1.643 for elevation and 0.357 for depression. For a T grad of 50.8, corresponding height would be read on scale AA as + 64.3 feet or — 64.3 feet. Horizontal distance would similarly be read on scale AD, opposite scale AC, as 76.6 feet for either of the above inclinometer readings. Since the inclinometers on models FP-9 and FP-12 are graduated directly in terms of sine, the vertical departure or horizontal distance correction would be read opposite 1 + sine scale for both elevation and depression.

The A scales are graduated for distances to 500 feet and heights 1 foot and greater above or below horizontal. Although 36 feet is the minimum slant distance that can be measured with the Barr and Stroud dendrometer, the scale for horizontal distance was extended downward to 18 feet to accommodate a slant distance of 36 feet with an inclination of 60°.

The B scales attach to the reverse side of the slide rule and are used for converting combinations of T and F grad to stem diameter in inches. With the index set opposite T grad, diameter is read opposite F grad on scale BC for F grads of 64 and smaller (stems 0 to 7.9 inches), and opposite F grad on scale BA for F grads of 65 and larger (stems 8.3 to 160 inches). Thus, for a T grad of 50.8, diameter would be indicated as 5.2 and 18.4 inches, respectively, for F grads of 60.0 and 80.0.

Scales BB and BC are proportioned to cover the upper two-thirds of the center bar so that the C scale of the underlying slide rule is exposed. If scale BD is positioned below the D scale on the lower rail of the underlying rule, the C and D scales are available for multiplication and division, either for bark thickness corrections or unrelated problems. Figure 2 shows the arrangement of the scales after mounting.

Accuracy of the slide rule is well within the tolerances claimed for the instrument itself. Diameters read from the 10-inch rule for a range of random settings correspond closely to diameters derived from tables supplied with the instrument, and are obtained more conveniently in less time.

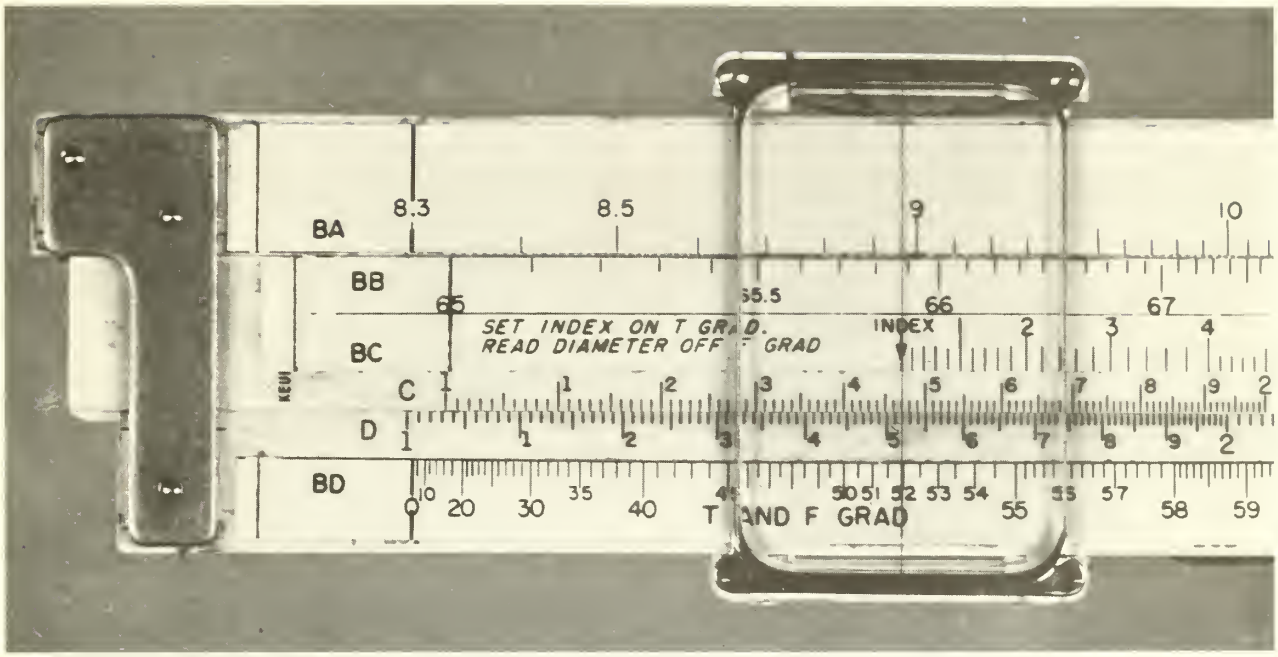

Figure 2.—*Scales BB, BC, and BD are positioned to leave exposed the C and D scales of the underlying slide rule.*

Although the slide rule is speedier than table lookup, its use with computer-processing should be confined to field checks, or to measuring trees where obstructed visibility may result in confusion and lead to undetected errors. STX computer processing will accommodate such direct measurements interchangeably with unconverted instrument readings if the tree input data card is punched appropriately, but field recording for a given tree must be on one basis or the other.

ATTACHING THE SCALES

The scales require a double-faced slide rule. The following procedure is suggested to assure accurate scale alignment and free movement of cursor and center bar.

1. Choose a rule that has ample clearance for the scale-paper stock and mounting adhesive. Test this by sliding two thicknesses of the paper stock strip under the cursor glass and under the end brackets on each side of the rule. If necessary, clearance for the glass can be obtained with shims. A slide rule requiring additional clearance through the end brackets should be avoided.

2. Before proceeding with scale attachment, adjust the rule so that the hairlines are aligned with the indexes on both sides. Fix the cursor in this position with a cardboard block and masking tape.

3. Slice the scales accurately along the scale line and trim to required width. Allow a margin of 1/16 inch at the outside edges of upper and lower rail scales. A sharp knife and steel straightedge are better for this purpose than conventional papercutters.

4. Starting with the center bar, slide the paper scale under the window glass until the index line is precisely under the hairline, and line up the scale with the side of the bar. Trim excess length to allow a margin of at least ½ inch on each end of the slide, but do not cut off the match lines. Hold the scale in this position with a stout paper clamp (fig. 3). Apply a thin, even coat of rubber cement to both the rule and scale surface to the right of the clamp. Allow a few moments for the cement to set, then press the scale to the rule, rolling it in place from the clamp out to the right end.

5. Remove the center bar, and attach the left side of the scale. Clean the bar and rail edges, and, if necessary, trim the scale so that the bar will again slide freely between the rails. Attach the right side of the scales to the upper and lower rails, in the same way, trimming length to fit between the end brackets. Clean and trim the scales so that the center

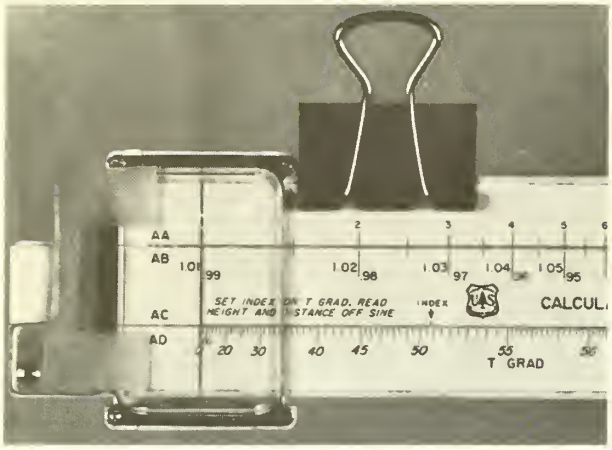

Figure 3.—*Shows cursor fixed in position with hairline adjusted to indexes of underlying slide rule, and paper scale overlay held in place before cementing.*

bar slides freely, then turn the rule over and repeat.

6. Release the cursor, and attach the left side of the scales to the upper and lower rails on both sides of the rule.

When the scales are aligned correctly, the match lines on the center bar will correspond with those on the rails, and the indexes on both sides of the rule will be opposite the same T grad.

LITERATURE CITED

1. Bruce, David.
   1967. A dendrometer field calculator. J. Forest. 65: 566-567.
2. Grosenbaugh, L. R.
   1963. Optical dendrometers for out-of-reach diameters: a conspectus and some new theory. Forest Sci. Monogr. 4, 47 pp.
3. Grosenbaugh, L. R.
   1967. STX—Fortran-4 program for estimates of tree population from 3P sample-tree-measurements. USDA Forest Serv. Res. Pap. PSW-13 (rev.), 76 pp. Pacific Southwest Forest and Range Exp. Sta., Berkeley, Calif.

SOUTHERN FOREST EXPERIMENT STATION

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REPLACEMENT PLANTING OF SOUTHERN PINES UNSUCCESSFUL

Philip C. Wakeley

SOUTHERN FOREST EXPERIMENT STATION

Three decades' survival and growth of replacements planted at stand age 1 or 2 years were far inferior to those of the original trees. This was true regardless of plantation spacing, percentage of fail spots, or intensity of thinning.

Observations continued through full pulpwood rotations in slash, loblolly, and longleaf pines planted at Bogalusa, Louisiana, have shown the general inadvisability of replacement planting of southern pines. Even at initial spacing as wide as 8 by 8 feet and with initial survival of original trees as low as 69 percent, replacements survived and grew too poorly, and produced too little pulpwood, to justify the cost of planting them. These results confirm and extend conclusions previously drawn from more widely spaced slash pine plantations in Georgia, at ages up to 16 years *(2, 3, 4, 5)*.

EXPERIMENTAL MATERIAL

The experimental plantations at Bogalusa are described in a forthcoming publication *(6)*. They included three 1-acre squares of slash pine of northeastern Florida provenance, three of loblolly of local southeastern Louisiana provenance, and three of longleaf, likewise of southeastern Louisiana origin. All were established with root-pruned, 1-0 nursery seedlings barplanted in shallow furrows on grassy, slightly brushy sites on which old-growth longleaf pine had been clearcut 4 to 6 years previously.[1] Spacings of 5 by 5, 6 by 6, and 8 by 8 feet occupied 1 acre apiece of the slash and loblolly; in longleaf the three spacings tested, also on 1 acre each, were 6 by 6, 8 and 8, and 10 by 10 feet.

When the slash and longleaf plantations had completed one growing season and the loblolly plantations had completed two, the 14 percent of fail spots in the slash, 4 percent in the longleaf, and 31 percent in the loblolly were replanted with root-pruned, 1-0 nursery seedlings of the same species and provenances as those planted before. There is evidence that the slash replacements were about equal to the original seedlings in physiological quality (that is,

[1] The sites were owned by the Great Southern Lumber Co., which, with its successor, Gaylord Container Corp. (now succeeded in turn by Crown Zellerbach Corp.) cooperated by furnishing planting stock, protecting and thinning the stands, and helping make the final measurements.

in capacity for survival and growth) and that the loblolly replacements were of better quality than the originals. The longleaf replacements, however, were distinctly inferior to the seedlings originally planted.

No thinnings were made in the longleaf prior to final measurement, but, when the slash plantations had completed 15 and the loblolly plantations had completed 19 growing seasons, light and heavy thinnings were tested in each spacing of these species. The thinnings, together with unthinned checks, were applied in Latin-square designs. Although they salvaged some large trees heavily infected with fusiform rust, they were mainly from below. They removed numerous replacement trees, including many of less than pulpwood size. Because replacements were not distinguished from originals in the thinnings, their poorer survival can be presented most reliably in terms of the unthinned checks. Thinning affected height growth only slightly, however, and the poorer height growth of the replacements is shown more accurately by the means of the larger populations on unthinned and thinned plots combined.

Depending on species, the plantations were remeasured annually for the first 5 or 10 years, and at approximately 5-year intervals thereafter—age 25 excepted. At ages 15 and 18 or 20, height measurements were limited to random-sample trees, which in some instances included very few replacements; the mean-height values computed for replacements at these ages were correspondingly erratic. Complete final measurements of all surviving trees were made when the original slash and longleaf trees were 30 years and the original loblollies were 34 years in plantation. After this measurement, the stands were irregularly opened up to release selected trees for breeding experiments.

Most of the trees of each species were planted on one to three of four locally common soil types, Susquehanna, Norfolk, Kalmia, and Myatt very fine sandy loams *(1)*; the slash pine plots, however, included small areas of three other soils. Results were analyzed by spacing × thinning-treatment × soil-type combinations. Soil differences had no discernible effect on the results of replacement planting, but analyzing separately by soils served to replicate the observations and hence to strengthen the conclusions.

RESULTS

Figure 1 is representative of the courses of survival and height growth of original and replacement trees of the three species. In practically all spacing × thinning-treatment × soil-type combinations of all three species, the replacements' survival fell off more rapidly with increasing age, and their height increased less with increasing age, than did those of the originals.

The mean final survival of original trees on the slash check plots (all spacings and soils combined) was 50 percent. That of the replacements was 21 percent.

On the unthinned loblolly check plots the mean final survivals were 41 for original trees and 6 percent for replacements. In this species the early survival of the replacements was generally better than that of the original trees, but postponement of replacement planting until the second year evidently created a handicap that the younger trees could not overcome.

In longleaf pine, final mean survival of original trees was 42 percent, as against 1 percent for replacements. As previously noted, however, the longleaf replacements, although planted only 1 year after the originals, were of poorer quality.

At final reexamination the mean total height of all surviving original slash pines, then 30 years in plantation, was 60 feet; that of the surviving slash pine replacements, at 29 years in plantation, was 51 feet. The corresponding means for loblolly originals at 34 years and replacements at 32 years were 62 and 44 feet. (Comparable values cannot be given for longleaf, as only a single replacement survived.) In slash and loblolly the height superiorities of original over replacement trees were roughly equivalent to two and three extra pulpwood bolts, respectively, at the bottoms of the trunks, where they have the greatest volume and value (fig. 2).

At final reexamination, slash pine originals averaged 7.3 inches d.b.h. and replacements averaged 5.9. The loblolly originals averaged 7.6 inches d.b.h., and the replacements 4.5.

In all three species the mean proportions of replacements in the live stands decreased sharply between the time of replacement planting and that of final reexamination. In the unthinned slash pine check plots, in which no

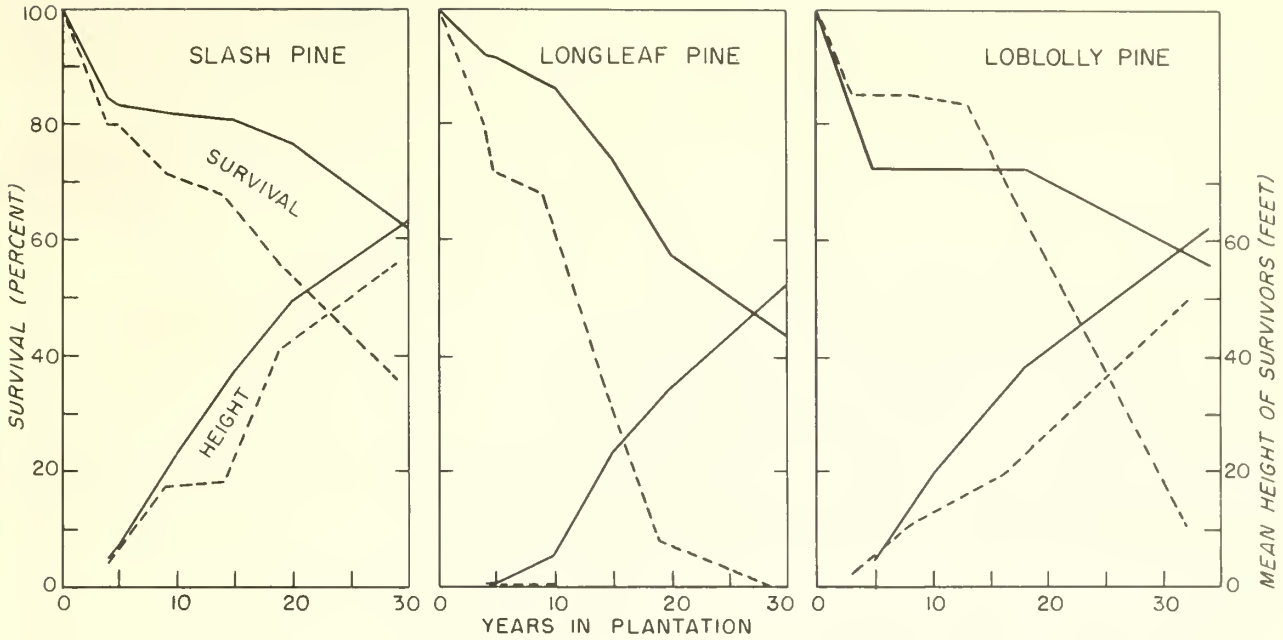

Figure 1.—*Survival and growth of original pines (solid lines) planted at 8- by 8-foot spacing and of replacements (broken lines) planted 1 year later (slash and longleaf) or 2 years later (loblolly).*

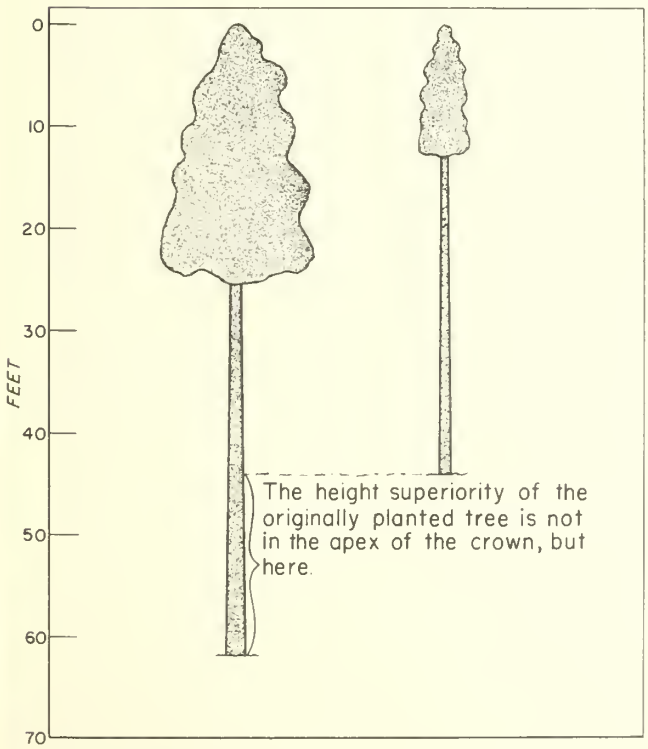

Figure 2.—*Relative sizes, at final measurement, of average original loblolly pine (left) and average replacement planted 2 years later.*

bias was introduced by the thinning from below, the proportion decreased from 14.3 to 5.7 percent. In the unthinned loblolly checks it decreased from 31.2 percent to 4.1 percent. In longleaf it decreased from 4.1 to 0.1 percent. These values reflect the relatively greater attrition of replacement-tree than of original-tree populations with passage of time.

Replacements contributed little to dominant crown canopies, sawtimber volume, or even pulpwood volume at pulpwood rotation age.

At final reexamination, only 31 percent of the slash replacements that survived (6.7 percent of all that had been planted) were dominant or codominant. The corresponding figures for loblolly replacements were 10 and 0.6 percent. The sole surviving longleaf replacement, a codominant, constituted 1.1 percent of all replacements planted.

A mere 2.1 percent of the slash replacements that survived (0.4 percent of those planted) were of sawtimber size (10.6 or more inches d.b.h.) and not a single longleaf or loblolly replacement reached this size.

For all slash pine spacings × thinning-treatments combined, replacements made up 4.1

percent of the total live pulpwood volume at final reexamination. The corresponding values for longleaf and loblolly replacements were 0.1 and 1.0 percent. The replacements could not have contributed appreciably to any volume removed in thinning, for many of those cut then were still below pulpwood size.

Replacement trees and especially the original trees tended to grow better at the wider spacings, and both tended to grow slightly better on thinned than on unthinned plots, though removal of trees in thinning generally resulted in lower final survival. The differences among spacing or thinning treatments, however, were far less strongly marked than those between original trees and replacements.

DISCUSSION

At any given spacing, replanting of fail spots costs more per tree than does original planting. Replacement planting cannot be done by machine. Doing it by hand involves not only time spent searching for blank spots but also more walking time from tree to tree than does hand-planting of the original trees. From the small contributions made to the final stands described in this note, it seems clear that replacement planting was not worth the seedlings and labor. It appeared most nearly justifiable in the heavily thinned portion of the slash pine at 8- by 8-foot spacing.

To utilize fully the capacity of the site at spacings of 8 by 8 feet or wider, replacement planting may be advisable when initial survival is much lower than 70 percent. Even then, though, it would seem worthwhile only if done the first year after the original planting, and with seedlings of physiological quality high enough to insure rapid early growth. At wide spacings, such replacements should add appreciably more to final yields than did those in the study reported here. In view, however, of the handicap that their late start imposes on replacement trees, the better course would seem to do the original planting with stock of such good quality as to render initial mortality negligible and the replanting of fail spots unnecessary.

LITERATURE CITED

1. Anderson, A. C., Manifold, C. B., Elwell, J. A. and others.
   1925. Soil survey of Washington Parish, Louisiana. USDA Bur. Soils Advance Sheets 1922: 345-390.
2. Bennett, F. A.
   1954. Interplanted slash pine fails. Southern Lumberman 189(2369): 166.
3. Bennett, F. A.
   1954. Reduction in growth of interplanted slash pine. USDA Forest Serv. Southeast. Forest Exp. Sta. Res. Notes 55, 2 pp.
4. Bennett, F. A.
   1956. Growth of slash pine plantations on the George Walton Experimental Forest. USDA Forest Serv. Southeast. Forest Exp. Sta., Sta. Pap. 66, 21 pp.
5. Schultz, A. J.
   1961. A second report on interplanted slash pine. USDA Forest Serv. Southeast. Forest Exp. Sta. Res. Notes 154, 2 pp.
6. Wakeley, P. C.
   1969. Results of southern pine planting experiments established in the middle twenties. J. Forest. (In press).

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1968

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FOLIAGE WEIGHT AND STEM GROWTH OF LONGLEAF PINE

William D. Boyer

SOUTHERN FOREST EXPERIMENT STATION

In 45- to 60-year-old stands with densities ranging from nine to 47 trees per acre, an average of 13.2 cubic feet of wood per year was produced per thousand pounds of new needles.

Tree growth is limited by photosynthetic efficiency and the amount of photosynthetic surface present. In a particular environment, the quantity of foliage required to achieve a given amount of growth is probably a good index of photosynthetic efficiency. This note presents ratios between growth and foliage weight of longleaf pine *(Pinus palustris* Mill.) in lightly stocked second-growth stands in southwestern Alabama.

The stands ranged from 45 to 60 years old and averaged 52 years. Mean site indexes ranged from 65 to 79 and averaged 73 feet at age 50. Densities of 9, 18, 27, 36, and 45 square feet of basal area were randomly assigned among five 2.5-acre plots in each of two blocks. Initial stand densities were about 60 square feet of basal area per acre. Plots were thinned to prescribed densities early in 1957. All residual trees were 9 inches d.b.h. or larger, and plot averages ranged from 13.1 to 14.1 inches.

Tree growth and needle production were recorded on the central 0.9 acre of each 2.5-acre plot. Diameters were measured initially in March 1957 and again in March 1962 to determine 5-year growth. Merchantable cubic foot volumes to a 3-inch top (inside bark) were estimated from a local volume table.

Litter was sampled from July 1, 1960, through June 1963 in nine ¼-milacre traps per plot. Litter was collected monthly, ovendried, and weighed, and the pine needle fraction was determined. Since most longleaf pine needles are shed during the late summer and fall of their second year, those collected after July 1, 1960, had emerged during or after 1959. Thus, estimates of needle production are available for 1959 through 1961—3 of the 5 years of the growth period. There was little change in annual needle litter production, which averaged 1,299 pounds per acre in 1960-61; 1,346 pounds in 1961-62; and 1,216 pounds in 1962-63. Presumably, the needles produced and shed each year were in balance and annual fall was equivalent to production.

The ratios between stem growth and foliage weight are given in table 1 for each of the

five stand density classes. The dry weight of foliage produced annually averaged 51 pounds per tree. Average annual growth per 1,000 pounds of foliage was 13.2 cubic feet of stem volume and 0.45 square foot of basal area. Growth per unit of foliage appeared to decline with increasing stand density, but plot-to-plot variation was too great to confirm this decline.

Table 1.—*Annual growth and foliage production of longleaf pine*

Trees per acre (number)	Annual foliage production per tree	Annual growth per 1,000 pounds foliage	
		Basal area	Stem volume
	Pounds, dry weight	*Square feet*	*Cubic feet*
9	69	0.49	14.6
18	46	.48	14.4
26	48	.43	12.5
36	46	.43	12.7
47	45	.40	11.7
Average 27	51	.45	13.2

Relations between wood volume increment and foliage weight have been reported for other coniferous species. These data have been converted to the units of the present study in table 2. Among the species observed, only black spruce and Scotch pine had lower ratios of growth to foliage weight than longleaf pine.

LITERATURE CITED

1. Kittredge, J.
   1944. Estimation of the amount of foliage of trees and stands. J. Forest. 42: 905-912.
2. Mar:Moller, C.
   1947. The effect of thinning, age, and site on foliage, increment, and loss of dry matter. J. Forest. 45: 393-404.
3. Satoo, T.
   1967. Efficiency and quantity of leaves of closed stands of *Cryptomeria japonica* as influenced by site quality. *In* 14th Congr. Proc., Int. Union Forest. Res. Organ. Vol. 2: 395-404.
4. Weetman, G. F., and Harland, R.
   1964. Foliage and wood production in unthinned black spruce in northern Quebec. Forest Sci. 10: 80-88.
5. Wilde, S. A.
   1967. Production of energy material by forest stands as related to supply of soil water. Silva Fennica 1(1): 31-44.

Table 2.—*Ratios of stem growth to foliage weight*

Species	Location	Volume growth per 1,000 pounds foliage	Source
Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)	Switzerland	29.3	*(1)*
Jack pine (*Pinus banksiana* Lamb.)	Minnesota	19.7	*(1)*
Scotch pine (*P. sylvestris* L.)	Germany	12.0	*(1)*
White pine (*P. strobus* L.)	Vermont	32.9	*(1)*
Red pine (*P. resinosa* Ait.)	Vermont	15.1	*(1)*
Norway spruce (*Picea abies* (L.) Karst.)	Denmark	22.7	*(2)*
Cryptomeria (*Cryptomeria japonica* Don.)	Japan	16.3	*(3)*
Black spruce (*Picea mariana* (Mill.) B.S.P.)	Quebec	10.0	*(4)*
Red pine (*P. resinosa)*	Wisconsin	[1] 52.5	*(5)*
Longleaf pine (*P. palustris)*	Alabama	13.2	Present study

[1] Assuming a specific gravity of 0.4.

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PRUNING TO REDUCE FUSIFORM-RUST DAMAGE NOT JUSTIFIED ON YOUNG SLASH PINES

Hans G. Enghardt,[1] Lloyd F. Smith, and O. O. Wells

SOUTHERN FOREST EXPERIMENT STATION

Neither early removal of cankered branches nor complete pruning to 60 percent of total height reduced fusiform-rust stem infection enough to warrant the treatments in large slash pine plantations.

Fusiform rust, caused by *Cronartium fusiforme* (Hedgc. & Hunt ex Cumm.), is the most serious disease in slash pine *(Pinus elliottii* Engelm.) plantations *(6)*. In spring, spores produced on the leaves of oaks infect new shoots of nearby pines and cause cankers that may degrade or kill trees. Branch cankers that originate within about 15 inches of the stem often grow into the trunk *(4)*. Hence, in the absence of conclusive experimental data, pruning of infected limbs has often been recommended to reduce damage to main stems *(1, 2, 3, 5)*. The studies reported here were begun between 1958 and 1962 in young slash pine plantations near Alexandria, Louisiana, and Gulfport, Mississippi, to provide the necessary data.

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METHODS

In Louisiana, tests were started in 1958 in a 2- and a 5-year-old plantation. In 1962, a study was begun in a 3-year-old plantation. Pruning treatments ranged from removing diseased branches once, at age 2, 3, 4, or 5 years, to repeated pruning in four different years. In two additional treatments, all branches, diseased and healthy, were removed to two-thirds of total height in the oldest stand for 3 years. Limbs higher than 17 feet were not removed. In these two treatments, pruning was done on all trees per plot or on 200 potential crop trees per acre selected for form and freedom from rust. Plot sizes ranged from 0.10 to 0.25 acre in the different tests, and treatments were replicated three times. Canker counts and man-hours expended were recorded.

A single pruning method was tested in the Mississippi study. In 1960, when the trees were 3 years old and averaged about 7 feet tall, all branches were removed to about 60 percent of total height. At age 5, when heights averaged 12 feet, the treatment was repeated. The final canker count was made at age 6.

Four 1-acre plots were pruned and four were controls.

In all studies, small branches were removed with pruning shears, and large ones with a fine-toothed carpenter's saw. Differences in cankering due to treatment were analyzed at the 0.05 level with Duncan's multiple range test.

RESULTS

1958 Louisiana Study

Twenty of the 696 trees per acre in the 2-year-old plantation had one or more trunk cankers, and 88 trees per acre had branch cankers when the study was installed. Six years later, the 13-percentage-point difference in infection between repeatedly pruned and unpruned trees was not statistically significant (table 1). Cankered limbs were found and removed from 2-year-old trees in less than 2 man-hours per acre. More than twice as much time was needed to accomplish the same task when trees were 4 years old, and four repeated examinations and prunings required almost 13 man-hours per acre.

None of the pruning treatments significantly decreased stem cankering in the 5-year-old plantation. Originally, the stand had 628 trees per acre; 19 percent of the trees had stem infections and 27 percent had branch cankers. The percentage of trees with stem infection approximately doubled over a 6-year period (table 1). Labor requirements ranged from 2.3 man-hours per acre for tree examination and one pruning to more than 20 hours for the most intensive pruning treatment.

Pruning 200 crop trees per acre required 12.7 man-hours in the 5-year-old plantation. Six years after treatment, 20 percent of the pruned trees had stem cankers.

1962 Louisiana Study

Pruning in the earlier study was done in April. Between mid-April and mid-June, the number of cankers on branch wood that had been exposed to infection during the spring of the previous year increased threefold. This increase suggested that pruning should be done later in the year, when new infections are more evident. Consequently, in the second study pruning was done in late summer. It was started in a 3-year-old plantation with 880 trees per acre; 14 percent had stem infections and 15 percent had branch infections.

Pruning at age 3 and repeated annual pruning significantly reduced trunk infections; single treatments at ages 4 and 5 were ineffective (table 2). However, even four prunings starting at age 3 resulted in only a 6-percent-

Table 1.—*Stem infection, stocking, and total pruning time per acre—1958 Louisiana study*

Treatment	Stem infection		Trees		Pruning time
	Initial	After 6 years	Initial	After 6 years	
	Percent		*Number*		*Man-hours*
2-year-old plantation					
Prune canker limbs at age 2, 4, 5, and 6	2.8	39.8[1]	676	644	12.8
Prune canker limbs once at age 2	1.7	49.0	696	680	1.8
Prune canker limbs once at age 5	4.2	43.6	688	668	4.3
No pruning	2.4	53.1	716	696	...
5-year-old plantation					
Prune canker limbs at age 5 and 8	17.9	38.8	588	524	6.2
Prune canker limbs once at age 5	20.4	41.1	636	572	2.3
Prune all trees	23.3	40.0	588	520	20.1
No pruning	18.8	46.8	668	616	...

[1] Values connected by the same vertical line do not differ significantly at the 0.05 level.

Table 2.—*Stem infection, stocking, and total pruning time per acre—1962 Louisiana study*

Treatment	Stem infection		Trees		Pruning time
	Initial	After 4 years	Initial	After 4 years	
	Percent		*Number*		*Man-hours*
Prune canker limbs at age 3, 4, 5, and 6	13.2	14.3[1]	912	832	10.6
Prune canker limbs once at age 3	13.4	15.1	872	804	1.5
Prune canker limbs once at age 4	13.9	17.2	832	756	2.9
Prune canker limbs once at age 5	13.2	19.5	896	816	3.4
No pruning	14.3	20.3	888	812	.

[1] Values connected by the same vertical line do not differ significantly at the 0.05 level.

age-point reduction in stem infections. One pruning at age 3 was as effective as multiple pruning.

Mississippi Study

In a stand of 353 trees per acre, rust infection before treatment was almost identical on pruned and check plots—one-fourth of the trees had diseased branches, and 12 percent had stem cankers. At age 6, 3 years after pruning was started, there were 318 surviving trees per acre. Stem infection averaged 35 percent on pruned and 55 percent on unpruned plots. Although the reduction in stem cankers was statistically significant, infection was still a major problem.

DISCUSSION

Pruning costs were substantial, and the benefits were small and erratic. In the Louisiana tests, 20.1 man-hours were required to prune both diseased and healthy limbs to a height of 17 feet, and 12.7 man-hours were expended selecting and pruning 200 crop trees per acre. Removing only infected branches in four different years took 10.6 man-hours per acre. Landowners cannot justify the expense of these operations solely for rust reduction.

Why were the treatments ineffective? Some diseased branches may not have been identified early enough to remove them before infection spread to the trunk. The high rate of infection when all branches were removed to a height of 17 feet suggests another reason, however. Numerous cankers were found on internodes along the pruned sections of stems that had no cankers when pruning was started. Initial infections probably occurred along the bole on susceptible tissue of buds and sprouts which develop on the main stems of slash pines. In the studies, pruning appeared to favor the growth of adventitious sprouts.

LITERATURE CITED

1. Harms, W. R.
   1961. Growth of fusiform cankers on young slash pine. USDA Forest Serv. Southeast. Forest Exp. Sta. Res. Notes 159, 2 pp.
2. Lindgren, R. M.
   1950. Damage from heavy fusiform cankering in '49 can be reduced. Forest Farmer 9(4): 9.
3. Siggers, P. V.
   1946. Fusiform rust, a threat to slash pine plantations. Miss. Agr. Exp. Sta. Inform. Sheet 362, 2 pp.
4. Siggers, P. V.
   1955. Control of the fusiform rust of southern pines. J. Forest. 53: 442-446.
5. Verrall, A. F.
   1961. Spread of *Cronartium fusiforme* branch infections. (Abstr.) Phytopathology 51: 646.
6. Wakeley, P. C.
   1954. Planting the southern pines. USDA Forest Serv. Agr. Monogr. 18, 233 pp.

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1969

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INTROGRESSION WITH SHORTLEAF PINE MAY EXPLAIN RUST RESISTANCE IN WESTERN LOBLOLLY PINE

R. C. Hare and G. L. Switzer[1]

SOUTHERN FOREST EXPERIMENT STATION

Electrophoretic patterns of seed proteins and similarities in morphological characteristics suggest introgression between western sources of loblolly pine (Pinus taeda *L.) and shortleaf pine* (P. echinata *Mill.). Fusiform rust resistance of western loblolly may arise from such introgression.*

Loblolly pine *(Pinus taeda* L.), over most of its range in the Southern United States, is highly susceptible to the fusiform rust fungus *(Cronartium fusiforme* Hedgc. & Hunt ex Cumm.). Sources west of the Mississippi River, however, have considerable resistance *(5, 6)*. Both shortleaf pine *(P. echinata* Mill.) and hybrids with loblolly are resistant *(3)*, and introgression with shortleaf has been suggested as the reason for resistance of loblolly from western sources *(6, 7)*. Anderson's *(1)* notation that " . . . all widespread eastern species which have so far been analyzed exhibit introgression along the Ozark-Texas axis, if they have a related taxon in that direction" supports this suggestion. We present morphological and biochemical evidence of loblolly-shortleaf introgression in the western portion of loblolly's range (roughly the Ozark-Texas axis of Anderson) which supports the possibility that resistance is caused by introgression.

In addition to rust resistance, shortleaf pine has shorter needles and fascicle sheaths, smaller seeds with thinner coats, and a tendency toward more cotyledons per seedling than loblolly pine. Hybrids are intermediate in these traits *(4)*. Switzer has made a morphological study of loblolly pine from 50 rangewide sources which shows that western sources tend to the shortleaf phenotype in each of these characteristics (table 1). Details will be published elsewhere.

Analyses of seed proteins by acrylamide gel electrophoresis also indicate introgression. Loblolly pine seeds from eight eastern sources (in Virginia, Maryland, Florida, and Georgia) and four western sources (in Oklahoma and Texas)

Table 1.—*Morphological characters of eastern and western provenances of loblolly pine*

Character and unit of measure	Eastern	Western
Needle length (cm.)	17.2	13.3
Sheath length (cm.)	1.0	.7
Needles per fascicle (No.)	3.2	3.0
Cotyledons (No.)	6.9	7.4
Seedcoat thickness (mm.)	.330	.277
Seed weight (mg.)	27.3	26.0

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were compared with shortleaf pine seeds from three places in Mississippi.

Extraction and electrophoresis were carried out at 4°C. Acetone powders were prepared by triturating seed contents in a centrifuge tube with a glass rod under acetone-petroleum ether 4:1 v/v, centrifuging, discarding the supernatant, and drying the pellet in an air stream. After screening, 50 mg. of acetone powder were stirred with 0.1 ml. of a pH 5.0 extracting solution which contained 15 percent sucrose, 0.4 percent Triton X-100, 0.5 percent $K_2S_2O_5$, 0.1 percent dithiothreitol, and 1.0 percent ascorbic acid. After 1 hr. the extract was centrifuged at 30,000 *g* for 10 min. Then 10 μl of the supernatant were layered on 6 percent polyacrylamide gel columns under pH 8.9 tris-glycine upper buffer. After electrophoresis at 4 ma. per tube, the protein bands were fixed in 12.5 percent trichloracetic acid for ½ hr., then stained with Coomassie blue *(2)*.

Results for each of three replicates were similar. Electrophoretic patterns were identical for shortleaf pine from all sources. Patterns for loblolly pine varied by source. A total of 22 protein bands developed. Fourteen were common to all loblolly and shortleaf pine seed sources, three were unique to shortleaf, and one was found only in loblolly (fig. 1). Two of the remaining four bands (A and B) occurred in shortleaf and some loblolly sources; the other two (C and D) were absent from shortleaf and some loblolly sources. Introgression was measured by giving each loblolly source a similarity rating based on 25 points each for the presence of bands A and B and for the absence of bands C and D. Examples are shown in figure 1, where a Georgia source rates 25 percent (bands B, C, and D present), and an Oklahoma source 100 percent (A and B present, C and D absent). All eastern loblolly sources averaged 34 percent similarity to shortleaf. Western sources averaged 88 percent. Three of the four western sources, but none of the eight eastern, rated 100 percent.

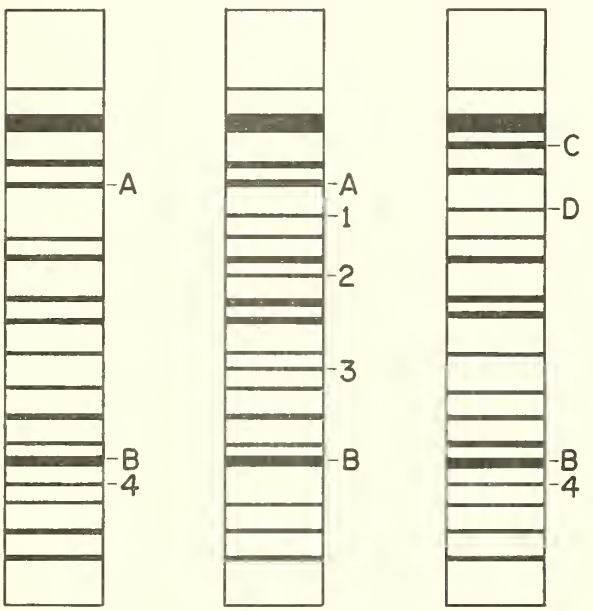

Figure 1.—*Protein bands for loblolly pine from Oklahoma (left) and Georgia (right) were compared with shortleaf pine (middle) for occurrence of bands A, B, C, and D. Bands 1, 2, and 3 were found only in shortleaf and band 4 only in loblolly pine.*

It seems fair to conclude that introgression with shortleaf pine is much more frequent in western than in eastern loblolly pine, and that this introgression may account for the fusiform-rust resistance of western sources.

LITERATURE CITED

1. Anderson, E.
   1953. Introgressive hybridization. Biol. Rev. 28: 280-307.
2. Chrambach, A., Reisfeld, R., Wyckoff, M., and Zaccari, J.
   1967. A procedure for rapid and sensitive staining of protein fractionated by polyacrylamide gel electrophoresis. Anal. Biochem. 20: 150-154.
3. Henry, B. W., and Bercaw, T. E.
   1956. Shortleaf-loblolly hybrid pines free of fusiform rust after 5 years' exposure. J. Forest. 54: 779.
4. Mergen, F., Stairs, G. R., and Snyder, E. B.
   1965. Natural and controlled loblolly × shortleaf pine hybrids in Mississippi. Forest Sci. 11: 306-314.
5. Wakeley, P. C.
   1944. Geographic source of loblolly pine seed. J. Forest. 42: 23-32.
6. Wells, O. O., and Wakeley, P. C.
   1966. Geographic variation in survival, growth, and fusiform-rust infection of planted loblolly pine. Forest Sci. Monogr. 11, 40 pp.
7. Zobel, B. J.
   1953. Are there natural loblolly-shortleaf pine hybrids? J. Forest. 51: 494-495.

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BENEFITS FROM THINNING BLACK WILLOW

R. L. Johnson and J. S. McKnight [1]

SOUTHERN FOREST EXPERIMENT STATION

Black willow stands 18 and 24 years old were cut from about 130 square feet of basal area per acre to near 95, 75, and 55 square feet. Growth was best on plots thinned to 55 square feet in the 24-year-old stand and to 95 square feet in the 18-year-old stand. The stands were along the Mississippi River.

One of the common tree species in the lower Mississippi Valley is black willow *(Salix nigra* Marsh.). It is concentrated in dense, even-aged stands along the river and its tributaries, often in association with cottonwood *(3)*. Black willow grows rapidly and usually matures in about 55 years *(1)*. The wood is used for factory lumber, commercial and package veneer, and pulpwood.

High density of stands often results in heavy mortality. If left alone, the trees tend to stagnate. Maisenhelder and Heavrin *(2)* contended that thinning would increase yields. The research reported here supports their contention.

THE STUDY

Two pole-sized stands along the Mississippi River batture were studied. The first, within a mile of Arkansas City, Arkansas, was 24 years old when treated in 1954 (fig. 1). Soil is Sharkey clay. Trees averaged 13.5 inches d.b.h. and were up to 115 feet tall. Basal area per acre averaged about 130 square feet, and total volume, about 3,700 cubic feet. There were 131 trees 5.1 inches d.b.h. and larger.

The second stand, about 10 miles south of Arkansas City, was treated in 1958 at age 18. Trees averaged 12.4 inches d.b.h.; dominants were up to 110 feet tall. The stand was on a Mhoon silty clay soil. A sand layer about 3 to 4 feet beneath the surface of two-thirds of the study area joined a nearby lake and probably held water throughout most of the growing season. Best growth occurred on this portion of the area. The stand averaged about 130 square feet of basal area and 3,700 cubic feet in 158 trees per acre 5.1 inches d.b.h. and larger.

[1] The authors are stationed at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Miss., by the Southern Forest Experiment Station in cooperation with the Mississippi Agricultural Experiment Station and the Southern Hardwood Forest Research Group.

Figure 1.—*Twenty-four-year-old black willow stand thinned from approximately 130 to 75 square feet basal area per acre.*

Four thinning treatments were tested on both areas:

Check. No thinning.

Light thinning. To about 95 square feet of basal area per acre.

Medium. To about 75 square feet.

Heavy. To about 55 square feet.

In addition, two diameter-limit cuts were made on the 24-year-old stand:

Large-tree removal. All trees larger than 14.9 inches d.b.h. were cut.

Small-tree removal. All trees smaller than 13 inches d.b.h. were cut.

Each treatment was replicated three times in a randomized block design. Plots comprised 1 acre in the older stand and ½ acre in the younger.

All trees were tagged after treatment. Diameters of living trees were measured every 2 years until 1964. Local volume tables were made from direct measurement of cut trees and Abney-level measurement of standing trees. Cubic-foot volumes were computed for merchantable wood up to a 4-inch d.i.b. top, board-foot volumes (Doyle) to a 12 inch d.i.b. top.

Differences due to treatment were evaluated at the 95-percent level of probability by Duncan's multiple-range test.

RESULTS

Results are presented separately by stand. They are for a 10-year period in the older stand and a 6-year period in the younger.

Older Stand

After treatment, stocking ranged from 51 trees per acre on heavily thinned plots to 131 trees on the check plots (table 1). In general, the higher the stocking, the greater the mortality. In 10 years, mortality on the check plots

Table 1.—*Data summary for the 24-year-old stand*

Treatment and measurement year	Trees	Basal area	Volume	
			Cordwood [1]	Saw logs [2]
	No.	*Sq. ft.*	*Cu. ft.*	*Bd. ft.*
Check				
1954	131	128.3	3,715	4,391
1964	73	114.9	3,597	10,066
Annual change	−5.8	−1.3	−12	568
Light thinning				
1954	98	93.9	2,690	2,216
1964	64	99.8	3,111	8,058
Annual change	−3.4	0.6	42	584
Medium thinning				
1954	76	79.0	2,303	2,583
1964	60	101.1	3,190	9,440
Annual change	−1.6	2.2	89	686
Heavy thinning				
1954	51	58.2	1,716	2,153
1964	47	87.8	2,821	9,544
Annual change	−0.4	3.0	110	739
Small tree removal				
1954	62	79.3	2,384	3,588
1964	45	86.7	2,797	9,916
Annual change	−1.7	0.7	41	633
Large tree removal				
1954	92	72.0	1,984	0
1964	64	90.7	2,780	6,143
Annual change	−2.8	1.9	80	614

[1] Based on trees 5.0 inches d.b.h. and larger.
[2] Based on trees 15.0 inches d.b.h. and larger.

was 44 percent, as compared to 8 percent on heavily thinned plots.

A diameter growth rate of less than 2 inches in 10 years may be considered slow for black willow, 2 to 5 inches medium, and more than 5 inches fast. A majority of the trees grew at the medium rate. But fast growers were from four to six times more numerous in the thinned plots than in the unthinned. Large-tree removal produced more fast growers than all other treatments and a higher proportion than all except heavy thinning. Best growth of any tree was 7½ inches.

Stand growth was defined as the total 10-year change in volume or basal area of the residual trees. Volumes and basal areas of trees that died during the period were not included in the totals for 1964. Cull trees were measured and included, but trees growing into merchantable size (5.1 inches d.b.h.) were not.

Relation between growth and residual basal area was linear—the lower the beginning basal area, the better was the growth. The range in growth was from minus 1.3 square feet per acre annually on the check plots to 3 square feet on the heavily thinned plots.

Volume growth also was best on heavily thinned plots—110 cubic feet or about 1.4 cords annually (allowing 80 cubic feet to the cord). Check plots lost volume (table 1) (fig. 2). Cubic-foot growth was significantly lower on the check plots than on those given heavy and medium thinnings and on those from which large trees were removed.

Sawtimber growth ranged from about 740 board feet per acre per year on heavily thinned plots to about 570 board feet on check plots. Ingrowth accounted for 37 to 56 percent of the total, depending on treatment.

Growth per tree increased as degree of thinning increased. Trees on heavily thinned plots grew about 1.5 times more basal area and cubic-foot volumes than those on check plots and 1.2 times more than those in each of the other treatments. Growth per tree was significantly higher after heavy thinning than after large-tree removal, light thinning, and no thinning. Small-tree removal and medium thinning also resulted in significantly higher individual-tree growth rates than no treatment.

Trees growing into pulpwood size (5.1 inches d.b.h.) during the decade were largely hackberry, privet, and pecan. Most were short and poorly formed. In 10 years, these trees added about 18 square feet of basal area per acre to the small-tree removal plots and about 5 square feet to the heavily thinned plots.

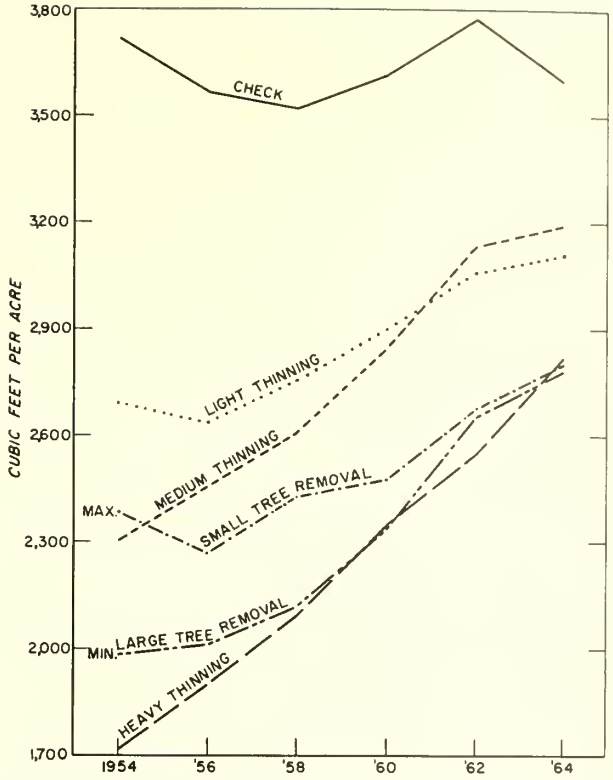

Figure 2.—*Cubic feet per acre for the 24-year-old stand.*

Younger Stand

In the younger stand, mortality from 1958 to 1964 reduced stocking of unthinned plots by about one-third, or 6 percent annually—more than twice the loss from mortality in thinned plots.

Fifty to 60 percent of the trees in the check and lightly thinned plots grew at the medium rate, whereas 60 to 80 percent of those on medium and heavily thinned plots grew fast (more than ½ inch per year). Percentage of fast growers rose as degree of thinning increased. Best growth of any tree, when projected on a 10-year basis, was 11½ inches.

Basal area growth was highest on the lightly thinned plots—4.3 square feet per acre. Plots given a medium and heavy thinning had a basal area growth of 4.0 and 3.9 square feet. Check plots lost growth. Two plots of each

treatment were underlain with the sand layer mentioned earlier. Depending on treatment, these plots annually grew 1.9 to 6.1 square feet of basal area per acre more than corresponding plots without the sand layer.

Cubic-foot growth followed the same pattern as basal area. It reached a high of 164 feet, or over 2 cords per acre per year, in the light thinning treatment that started with about 2,900 cubic feet (fig. 3). The two lightly thinned plots with the sand layer grew 2.9 cords annually. Cubic-foot growth was significantly lower on the check than in each of the thinning treatments.

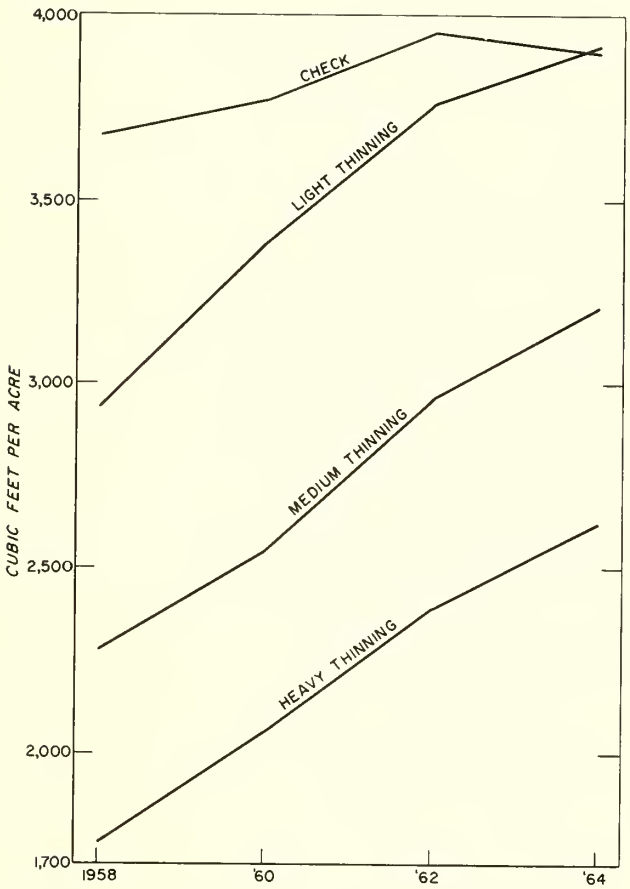

Figure 3.—*Cubic feet per acre for the 18-year-old stand.*

Sawtimber growth was good in all treatments, ranging from 803 board feet per acre annually on check plots to 1,152 board feet on lightly thinned plots (table 2). Ingrowth accounted for one-half to two-thirds of total growth, depending on treatment.

Table 2.—*Data summary for the 18-year-old stand*

Treatment and measurement year	Trees	Basal area	Volume	
			Cordwood [1]	Saw logs [2]
	No.	*Sq. ft.*	*Cu. ft.*	*Bd. ft.*
Check				
1958	158	131.3	3,676	1,922
1964	105	129.9	3,903	6,739
Annual change	−8.8	−0.3	38	803
Light thinning				
1958	90	99.9	2,932	3,457
1964	81	125.6	3,918	10,366
Annual change	−1.5	4.3	164	1,152
Medium thinning				
1958	80	79.2	2,274	1,409
1964	68	103.5	3,212	8,133
Annual change	−2.0	4.0	157	1,121
Heavy thinning				
1958	50	59.2	1,752	2,198
1964	46	82.4	2,625	8,045
Annual change	−0.7	3.9	146	975

[1] Based on trees 5.0 inches d.b.h. and larger.
[2] Based on trees 15.0 inches d.b.h. and larger.

As with the older stand, average growth of live trees increased as the degree of thinning increased. Compared with average basal area growth in heavily thinned plots, trees grew 84 percent as much after the medium thinning, 75 percent after light thinning, and 52 percent on check plots. The difference in individual-tree growths between heavily thinned and check plots was statistically significant.

Nonwillow species, primarily hackberry, invaded all plots and added about 3 square feet of basal area per acre to the medium and heavily thinned plots, 2 square feet to those lightly thinned, and less than 1 square foot to check plots.

Comparison of Stands

Even before treatment, differences between upper levels of stocking indicated that the site of the younger stand was superior to that of the older one. The younger stand contained 150 to 160 square feet of basal area as compared to 130 to 140 square feet in the older. At comparable basal areas, growth was considerably better in the younger stand. To simplify comparison between stands and treatments, average annual change in cubic-foot volume was

expressed as a percentage of the volume after treatment:

Treatment	Younger stand	Older stand
	– Percent –	
Unthinned	1.0	0
Light thinning	5.6	1.6
Medium thinning	6.9	3.9
Heavy thinning	8.3	6.4
Small-tree removal	.	1.7
Large-tree removal	..	4.0

Mortality did not differ greatly between study areas for the same treatment. Therefore, site potential is indicated by excluding mortality and basing growth only on trees that survived. For example, surviving trees in all treatments added between 3½ and 4 square feet of basal area and about 130 cubic feet annually on the poorer site, and between 5½ and 6 square feet and about 200 cubic feet on the better site. The better site supported more surviving trees and about 1/3 more growth per tree.

Survivor growth reveals another aspect to the thinning treatments. On both sites growth was about the same in all treatments, although the beginning levels of stocking were quite different (fig. 4). The only exception was heavy thinning on the better site, where the lower growth may have been the result of inadequate stocking.

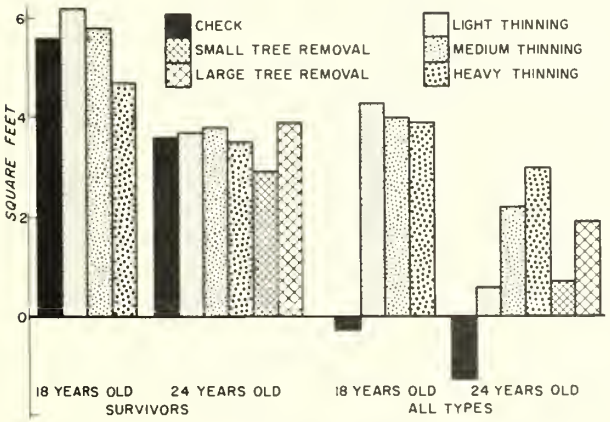

Figure 4.—*Annual basal area growth per acre.*

CONCLUSIONS

A major benefit to be derived from thinning willow is utilization of trees that would otherwise die. In this test selective thinning made available 2/3 to 2½ more cords per acre annually than could be obtained from unthinned stands.

Thinning also stimulates diameter growth of residuals. Survivor growth in this study was about the same whether spread over 47 or 73 trees on the poorer site and 68 or 105 on the better site. Growth was reduced on the better site when only 46 trees were left after thinning.

The best thinning in terms of subsequent growth depends on site. As indicated by the check plots, growth curves had probably flattened before thinning in both stands. But growth on the better site appeared to level off at about 130 square feet of basal area per acre and on the poorer site at about 90 square feet. On the good site then, a thinning interval of 6 years may be required to maintain the stand between 90 (the best base for growth) and 130 (where growth falls off) square feet. A cut every 10 years on the poorer site should confine the stand between 60 (minimum basal area for full site utilization) and 95 square feet. If site quality is unknown, thinning to about 70 square feet is probably the best compromise.

In this study, cutting the larger trees resulted in better growth than removal of the smaller trees. This finding is contradictory to what most foresters would expect. It can be partly explained by close scrutiny of individual plot data. After treatment, all three plots cut from above had basal areas and growth rates only slightly less than those of plots thinned at the medium rate. Two of the three plots cut from below had residual basal areas and growth rates close to those of lightly thinned plots; the third plot was nearer in basal area and subsequent growth to that after heavy thinning. Thus, growth rates after cutting of large or small trees were more a function of the residual basal area than the method of thinning.

It appears that either type of diameter-limit cutting may result in only slightly less growth than selective thinning if residual basal areas are equal. In the study, however, it was very difficult to control basal area in diameter-limit cuts. Other disadvantages are that spacing between trees cannot be manipulated nor can high-quality trees be favored.

Thinning was obviously beneficial in the black willow stands that were studied. In most stands in the lower Mississippi Valley, pre-

commercial thinning is probably desirable when dominant trees average 3 to 4 inches d.b.h. About 350 trees per acre should be left.

The responses to thinning reported in this paper should help forest managers to choose an appropriate density for the residual stand. A reasonable rule-of-thumb to follow in commercial thinnings is to remove trees until the average spacing, in feet, is 1.75 times the average tree diameter. For example, if the average d.b.h. is 10 inches, spacing between trees should average 17.5 feet. The resulting stand contains about 142 trees and 77 square feet of basal area per acre. Any time the factor falls below 1.5, thinning is probably needed, even on a good site. The site is probably not being fully utilized if the factor exceeds 2.0.

Where managers cannot follow the recommendations of this paper, a minimum of two commercial thinnings may be an acceptable compromise. General observations indicate that the first should take place when dominants average about 10 inches d.b.h., and the second, when they are about 16 inches d.b.h.

The final harvest should usually take place when dominants average about 20 to 24 inches d.b.h. If the stand is allowed to develop further, it may break up quickly, particularly if a drought occurs.

LITERATURE CITED

1. McKnight, J. S.
   1965. Black willow (*Salix nigra* Marsh.). *In* Silvics of forest trees of the United States, pp. 650-652. USDA Agr. Handbook 271.

2. Maisenhelder, L. C., and Heavrin, C. A.
   1957. Silvics and silviculture of the pioneer hardwoods—cottonwood and willow. Soc. Amer. Forest. Proc. 1956: 73-75.

3. Putnam, J. A., Furnival, G. M., and McKnight, J. S.
   1960. Management and inventory of southern hardwoods. USDA Agr. Handbook 181, 102 pp.

SOUTHERN FOREST EXPERIMENT STATION

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UNMANAGED GROWTH IN NORTH MISSISSIPPI UPLANDS

Hamlin L. Williston [1]

SOUTHERN FOREST EXPERIMENT STATION

In stands that have been protected from fire and cutting since the middle 1930's, but not otherwise managed, annual growth has averaged but 10 to 30 cubic feet per acre—largely because of cull competition and poor species composition.

Three natural areas, totaling 120 acres, have been maintained since early 1953 on the Tallahatchie Experimental Forest near Oxford, Mississippi. Activities of man have been largely excluded, since one of the objects is to learn how the timber stand will develop if unmanaged. No cutting has been done since the middle 1930's, when the tracts passed into Federal ownership. All fire has been excluded since 1935. The stands were measured at establishment and at approximately 5-year intervals thereafter. This note reports results as of 1967, after 15 growing seasons.

Forty-five permanent ¼-acre plots were located randomly over the 120 acres in 1953. The timber type on each was determined by Forest Survey standards.

Thirty-one plots fell in the upland hardwood type—i. e., the stands consisted mostly of oaks and hickories, with less than 25 percent of the basal area in pine. Three-fourths of these plots were on ridgetops and upper slopes; the rest were on middle and lower slopes. Average site index for shortleaf pine was 65 feet at 50 years. Fifty-year site index for white oaks or red oaks was judged to be 60 feet or less. Initial board-foot volumes, by the International ¼-inch rule, averaged 2,585 board feet per acre.

Five plots were classed as upland pine-hardwood—i. e., pines comprised 25 to 49 percent of the basal area, and the rest of the stand was chiefly oaks and hickories. These plots ran the gamut from lower slopes to ridgetops. Sawtimber volume in 1953 averaged 3,697 board feet per acre.

Nine plots were in the shortleaf type—i. e., pines made up at least 50 percent of the stand, with the rest mostly oaks and hickories. Seven of these plots were on middle and lower slopes that had once been cleared for pasture or crop-

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land. The average site index for shortleaf was estimated at 80 feet. In 1953 there were 3,644 board feet per acre.

Trees on the plots were tallied as to species, number, size, and quality classes. The quality classes were:

Desirable growing stock. Trees of desirable species and form, free of defects limiting present or future utility for pulpwood or saw logs, and in good vigor.

Overburden. Trees presently marketable but too defective or growing too slowly to increase in value if kept in the stand.

Culls. Trees of no present or foreseeable future value.

Development of the stands varied somewhat with forest type. In the upland hardwood type there was a substantial decrease in the number of saplings and pole-size trees (table 1). Most of the loss, however, was in species of low commercial value, such as blackjack oak, upland Shumard oak, and hickory. Basal area in the upland hardwood type remained constant at 71 square feet per acre during the 15-year period (table 2). Annual cubic-volume increase (table 3) of the merchantable stand averaged 9.9 cubic feet per acre, a growth rate of 1.9 percent. Sawtimber growth averaged 70 board feet per acre per year, an increase of 2.7 percent per year.

In the pine-hardwood stands approximately 60 percent of the saplings died during the study period. The stand of trees 5 inches d.b.h. and larger remained constant. There was a 19-percent increase in basal area to 82 square feet per acre; more than half of this increase was attributable to the pine component. The cubic volume increased 2.1 percent per year (15.3 cubic feet per acre). Sawtimber volume increased at the rate of 3.6 percent—134 board feet per acre per year; 82 percent of this increase was in pine.

In the shortleaf pine type there was a 6-percent increase in the number of saplings per acre, a 22-percent increase in pole-size trees, and a 65-percent increase in sawtimber trees. Basal area rose from 59 square feet to 87 square feet during the 15 years. Growth per acre per year averaged 30.0 cubic feet or 185 board feet.

Table 1.—*Stems per acre (all classes of trees, including culls)*

Forest type and species	1-4 inches d.b.h.		5-11 inches d.b.h.		Above 12 inches d.b.h.	
	1953	1967	1953	1967	1953	1967
	Number					
Upland hardwood						
Pine	6	...	7.1	6.5	2.0	3.8
White oak	1,104	780	27.0	26.5	8.3	11.1
Red oak	644	299	40.0	18.8	16.7	17.2
Hickory	696	410	11.7	8.9	3.2	3.6
Misc.	2,446	1,665	15.1	9.8	2.6	.8
Total	4,896	3,154	100.9	70.5	32.8	36.5
Pine-hardwood						
Pine	60	200	32.4	34.0	20.0	20.8
White oak	720	720	30.0	40.0	4.0	8.8
Red oak	920	40	46.0	24.0	8.8	8.0
Hickory	420	200	8.0	10.0	1.6	1.6
Misc.	2,440	740	...	2.0	.8	.8
Total	4,560	1,900	116.4	110.0	35.2	40.0
Shortleaf pine						
Pine	77	22	86.9	95.6	15.8	26.1
White oak	22	88	8.8	11.0	1.3	.8
Red oak	1,011	266	13.2	16.5	2.2	3.3
Hickory	11	11	7.7	7.7	.8	1.2
Misc.	3,275	4,285	16.5	31.0	...	1.7
Total	4,396	4,672	133.1	161.8	20.1	33.1

Table 2.—*Basal area per acre*

Forest type and species	March 1953			October 1967			Periodic growth
	Growing stock	Over-burden	Cull	Growing stock	Over-burden	Cull	
	Square feet						
Upland hardwood							
White oak	3.4	12.0	4.4	3.1	17.5	3.5	4.3
Red oak	7.5	18.7	7.2	3.3	22.3	3.5	−4.3
Hickory	1.5	3.3	1.9	.3	6.2	1.4	1.2
Pine	2.4	1.3	...	3.4	2.8	...	2.5
Misc.	.9	3.8	2.7	.5	2.5	.5	−3.9
Total	15.7	39.1	16.2	10.6	51.3	8.9	− .2
Pine-hardwood							
White oak	2.9	4.1	7.6	.5	16.7	5.3	7.9
Red oak	1.9	6.2	12.6	.6	9.1	6.4	−4.6
Hickory	...	.7	2.4	...	2.2	2.2	1.3
Pine	23.2	6.3	...	20.6	16.7	...	7.8
Misc.	...	.9	...	...	1.3	...	.4
Total	28.0	18.2	22.6	21.7	46.0	13.9	12.8
Shortleaf pine							
White oak	...	1.4	1.7	...	2.4	2.4	1.7
Red oak	.8	1.7	.9	...	7.4	1.5	5.5
Hickory	...	1.0	3.0	...	3.1	.6	− .3
Pine	33.4	10.7	...	38.0	23.5	...	17.4
Misc.	2.3	2.2	...	.7	6.7	.4	3.3
Total	36.5	17.0	5.6	38.7	43.1	4.9	27.6

Table 3.—*Cubic volume per acre*

Forest type and species	March 1953			October 1967			Periodic growth (exclusive of cull trees)
	Growing stock	Over-burden	Cull	Growing stock	Over-burden	Cull	
	Cubic feet						
Upland hardwood							
White oak	32.1	111.2	25.6	36.6	159.8	26.8	53.1
Red oak	72.8	174.1	68.7	41.3	243.7	24.5	38.1
Hickory	11.1	26.6	21.3	2.9	49.0	10.3	14.2
Pine	43.0	19.3	...	66.0	51.3	...	55.0
Misc.	6.1	29.4	14.1	7.9	15.4	11.8	−12.2
Total	165.1	360.6	129.7	154.7	519.2	73.4	148.2
Pine-hardwood							
White oak	15.9	43.4	46.7	2.6	116.2	43.1	59.5
Red oak	21.8	67.8	61.1	5.7	102.2	42.8	18.3
Hickory	...	6.5	10.9	...	15.7	12.5	9.2
Pine	500.1	80.6	...	404.9	312.6	...	136.8
Misc.	...	8.5	...	...	14.3	...	5.8
Total	537.8	206.8	118.7	413.2	561.0	98.4	229.6
Shortleaf pine							
White oak	...	12.6	6.9	...	18.6	15.5	6.0
Red oak	4.9	30.2	2.9	...	60.0	12.5	24.9
Hickory	...	11.5	18.0	...	22.8	3.0	11.3
Pine	472.1	167.7	...	583.8	443.5	...	387.5
Misc.	9.4	22.7	...	2.0	51.1	6.1	21.0
Total	486.4	244.7	27.8	585.8	596.0	37.1	450.7

The cubic growth rate was 4.1 percent and the board-foot growth rate, 5.1 percent. More than 86 percent of the growth has been in pine.

In volume of timber grown, these three unmanaged tracts have done very badly. Nor are there prospects for substantial improvement, for the proportion of desirable species—pine, white oak, and yellow-poplar—is too small in all but the shortleaf pine type, and reproduction of these species is scanty. An owner of such stands has two chief alternatives if he wishes to restore productivity. One is immediate conversion to pine by planting. The other is to make heavy improvement cuts that favor shortleaf pine on the ridges and slopes and the better hardwoods in the draws and minor bottoms. Intensive management of upland areas like these can achieve annual growth rates of 1 to 1.5 cords per acre, and eventually of 300 to 400 board feet of sawtimber per acre.

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SYCAMORE VARIATION IN THE LOWER MISSISSIPPI VALLEY

Dan Schmitt and James R. Wilcox [1] [2]

SOUTHERN FOREST EXPERIMENT STATION

Natural variation in 12 sycamore characters within and among three stands in the lower valley of the Mississippi River indicates that genetic improvement might best be accomplished by relaxed selection in natural stands, followed by intensive selection in foundation populations. Trees should probably be selected for straightness, form class, large diameter and height, and small crown.

The mounting evidence of success in programs for the genetic improvement of southern pines has led to thoughts of improving southern hardwoods, including American sycamore (*Platanus occidentalis* L.). Before such a program is begun, sufficient between-tree variation within stands to offer hope of success should be demonstrated. Then, it must be decided whether to select intensively from field populations, as was done with southern pines, or to defer intensive selection until foundation populations have been established. Intensive mass selection is the better choice when genetically superior individuals can usually be recognized in field populations.

This note reports natural variation of 12 characters within and among three sycamore stands in the lower valley of the Mississippi River. The amount of variation within stands is encouraging. The amount between stands suggests that relaxed selection may be best. Since selection is seldom for a single character, correlations between characters were also measured. All were small, and only the one between height and d.b.h. is likely to be helpful.

METHODS

Even-aged pole stands that contained at least 60 percent sycamore were sought on undisturbed sites in the lower Mississippi Valley. Only three suitable stands were found, one near Point Pleasant and one near Rosedale in

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[2] The authors thank Dennis Rankin, Duke University graduate student, who assisted in data collection and analysis; and the R.F. Learned, Anderson-Tully, and Chicago Mill and Lumber Companies, which located and provided stands for study.

Mississippi, and one near Vidalia, Louisiana (fig. 1). Ages of the stands ranged from 20 to 30 years; the one at Point Pleasant was oldest.

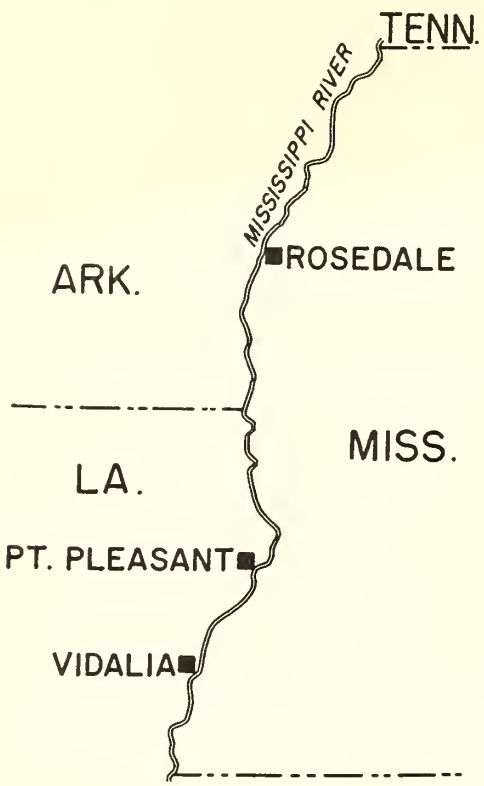

Figure 1.—*Location of stands.*

To obtain an indication of the comparative qualities of the sites, soil samples were collected in each stand and composited by depth classes of 0-10 inches, 10-40 inches, and 40-48 inches. The samples were analyzed for texture, pH, and phosphorus, potassium, and nitrogen contents by Walter M. Broadfoot of the USDA Forest Service at the Southern Hardwoods Laboratory.

In each stand, 30 dominant or codominant trees well away from edges (riverbank and trail) were randomly selected for measurement. Twelve tree characters which affect volume and quality were measured: total height, d.b.h., percent live crown, straightness, crown radius, Girard form class, limb angle, limb diameter, limb diameter-stem diameter ratio, lean, fiber length, and specific gravity.

Straightness was defined as the maximum deviation of the center of the stem from a line passing through the center at 33 feet and at the base of the tree. Crown radius was the average of two measurements of crown projection taken at right angles to each other. Limb angle and limb diameter were measured on three branches in the lower crown and averaged. Limb angle was determined with a plexiglass protractor. Stem diameter was measured at 33 feet. Lean was determined by measuring the maximum horizontal deflection at the base of a plumb bob hung from the stem axis at 33 feet. The remaining external tree characters were determined with conventional instruments.

For estimates of wood specific gravity and fiber length, two 11 mm. increment cores were extracted from opposite sides to the center of each tree at breast height. Measurements were made on four segments of each core, the 4-5, 9-10, 14-15, and 19-20 annual rings. Specific gravity was determined by the maximum-moisture method *(10)*, and fiber lengths of 60 normal, unbroken fibers from each ring segment were measured on an ampliscope *(3)*.

For each character, variances within and among stands were analyzed. Simple correlations were computed, by stand, for each pair of characters. The correlation coefficients were tested for homogeneity between stands *(11)*. Homogeneous pooled correlations were then examined for departure from zero. All statistical tests were made at the 0.01 level of confidence.

RESULTS AND DISCUSSION

Soils.—Although soil analyses alone are not completely reliable indicators (Broadfoot, personal communication), it is apparent from the soil data collected that the stands differ in site quality (table 1). The Rosedale soil contains less nitrogen and more sand than the others. The soils at Vidalia and Point Pleasant contain similar amounts of surface nitrogen, but Vidalia soil is highest in phosphorus content, and Point Pleasant soil in potassium content.

External characters.—Analyses of variance indicate that most characters were strongly affected by stand conditions (table 2). Statistically significant stand components of variance were found for eight characters: height, d.b.h., straightness, limb angle, limb diameter, lean,

Table 1.—*Soil properties of three sycamore stands in the Mississippi Delta*

Stand	pH	P	K	N	Sand	Silt	Clay
		– Pounds per acre –			– – – Percent – – –		
Rosedale							
Surface	7.5	83	200	360	83	3	14
2 feet	7.9	67	96	340	79	4	17
4 feet	8.0	67	48	240	84	1	15
Point Pleasant							
Surface	7.8	83	376	1,180	56	36	15
2 feet	7.7	67	304	500	49	39	23
4 feet	7.7	67	304	780	63	25	23
Vidalia							
Surface	7.8	144	192	1,180	52	33	8
2 feet	7.8	134	240	1,260	32	45	12
4 feet	8.0	134	184	2,640	26	51	12

Table 2.—*Means and variations in sycamore characters*

Character and unit of measure	Rosedale			Point Pleasant			Vidalia		
	Mean	Standard deviation	Range	Mean	Standard deviation	Range	Mean	Standard deviation	Range
Height (feet) [1]	75.2	5.38	66.0 -88.0	79.7	8.73	66.0 -106.0	89.7	6.01	77.0 -102.0
D.b.h. (inches) [1]	10.0	1.48	7.6 -13.8	12.7	2.35	9.2 - 19.2	12.1	2.07	8.1 - 16.0
Straightness (tenths of foot) [1]	3.0	2.06	.7 - 9.2	8.1	4.97	.0 - 17.0	2.5	1.65	.0 - 7.0
Limb angle (degrees) [1]	45.6	8.60	32.3 -64.7	56.1	10.50	41.0 - 83.3	44.0	5.96	31.0 - 59.7
Limb diameter (inches) [1]	1.9	.36	1.4 - 2.8	2.4	.59	1.6 - 4.3	2.1	.42	1.3 - 2.9
Lean (tenths of foot) [1]	1.8	1.71	.0 - 8.0	1.3	1.13	.0 - 4.0	.7	.47	.0 - 1.8
Live crown (percent)	53.9	7.48	39.0 -73.0	56.7	10.66	34.0 - 75.0	54.7	7.44	40.0 - 67.0
Crown radius (feet)	12.9	2.12	10.0 -18.0	13.6	2.24	11.0 - 19.5	14.1	2.21	9.0 - 19.0
Form class	82.9	2.38	76.5 -89.4	84.1	4.52	79.5 - 96.5	83.3	2.89	77.0 - 88.5
Limb diameter/stem diameter	.31	.06	.21 - .49	.30	.08	.19 - .57	.29	.07	.20 - .44
19-20 yr. fiber length (mm.) [1]	1.94	.054	1.70 - 2.30	2.06	.094	1.84 - 2.26	2.09	.115	1.84 - 2.26
19-20 yr. specific gravity [1]	.488	.028	.429- .550	.458	.032	.372- .552	.450	.222	.413- .502

[1] Variation among stands is statistically significant at the 0.01 level.

and 19-20 year fiber length and specific gravity. For percent live crown, crown radius, form class, and limb diameter-stem diameter ratio, components of variance did not vary significantly among stands.

It is helpful to consider the percentages of total variation attributable to stands and individual trees (table 3). For all characters except height, variation was at least as great among individual trees as among stands. Almost all the variation in percent live crown, crown radius, form class, and the ratio of limb diameter to stem diameter was among trees within stands.

Internal characters.—Specific gravity and fiber length varied significantly by stands and, at breast height, by ring segment. There was a positive, linear relation between specific gravity and ring age to the 20th annual ring. Fiber length had a similar but quadratic relation to ring age, indicating that fiber length was leveling off by age 20.

Table 3.—*Stand and tree variance components*

Trait	Stand component	Trees/stand component
	Percent of total	
Height	53.2	46.8
D.b.h.	32.6	67.4
Straightness	46.5	53.5
Limb angle	36.8	63.2
Limb diameter	24.9	75.1
Lean	14.4	85.6
Percent live crown	.0	100.0
Crown radius	3.8	96.2
Form class	.2	99.8
Limb diameter/stem diameter	.0	100.0
Fiber length (19-20 years)	41.3	58.7
Specific gravity (19-20 years)	33.3	66.7

The mean and range for specific gravity in the present study are similar to those previ-

ously reported for sycamore *(9, 14)*. At breast height, specific gravity in the present study increased with age, indicating the presence of juvenile wood. Wood in other native hardwoods develops similarly *(4, 13, 15)*.

Johnson and McElwee *(6)* found that sweetgum specific gravity varied significantly by stand but not by tree within stands. Since their reported variation pattern was not the same as that disclosed by other investigators for sweetgum *(5, 15)*, yellow-poplar *(7, 13)*, water tupelo *(8)*, or cottonwood *(4)*, Johnson and McElwee suggested that the small number of trees sampled within stands might account for their disparate results. In the present study, despite intensive within-stand sampling, stand differences in specific gravity were important. Moreover, specific gravity was lowest at Vidalia, where drainage and nutrient conditions were best, and highest on the nutritionally poorer Rosedale site. These observations suggest that site has an effect on sycamore's specific gravity.

The range found in fiber length—1.70 to 2.30 mm.—exceeds the 0.85 to 1.28 mm. reported by Boyce and Kaeiser *(1)* for cottonwood and the 1.24 to 1.72 mm. reported by Wilcox and Farmer *(16)*, also for cottonwood.

Sycamore fiber length at breast height increased with age but tended to level off at age 20. The pattern was not affected by stand differences. Similar fiber-length trends with age in both hardwoods and conifers have long been known *(12)*.

As in yellow-poplar *(13)* and water tupelo *(8)*, variation in fiber length of sycamore was relatively small, and that attributed to individual trees was only slightly larger than that attributed to stands.

Correlations.—Seven correlations differed significantly among stands—height:crown radius, d.b.h.:percent live crown, d.b.h.:specific gravity, percent live crown:fiber length, crown radius: form class, crown radius:limb diameter, and crown radius:lean. These relationships would be of little value in a selection program.

Seven of the 12 characters were relatively independent of each other: percent live crown, straightness, form class, limb angle, lean, fiber length, and specific gravity. Straightness was not correlated with any other character. Percent live crown was associated with crown radius ($r = 0.398$); form class with d.b.h. (—0.298) and limb diameter (—0.235). Limb angle was independent of all characters except d.b.h. (0.311). Twenty-year fiber length was associated with height (0.232) and lean (—0.223). Average fiber length per tree, however, was not correlated with lean. These correlations, though statistically significant, are small and account for little of the total variation. The two correlations accounting for relatively large amounts of the joint variation in the observed characters were height:d.b.h. (0.584) and d.b.h.:crown radius (0.568).

CONCLUSIONS

Substantial between-tree variation was found for all characters except perhaps height, despite large stand variance components for most characters. It should be noted that while each stand was sampled intensively only three stands were observed. Thus, variation within stands is better estimated than that between stands.

The scarcity of suitable stands and the patterns of variation suggest that intensive initial mass selection is not best for rapid genetic improvement of sycamore. The large tree-to-tree variation is not necessarily mainly genetic. Even the relatively uniform, pure, even-aged stands studied can be viewed as a mosaic of microsites. Since sycamore is sensitive to moisture and drainage conditions *(2)*, minor changes in relief can greatly affect performance. Further, within-stand variations in crown characters and form class are influenced as much by individual-tree competition as by genetic variation between trees. Since the best phenotypes are not necessarily the best genotypes, phenotypic selection is likely to be inefficient.

We recommend relatively relaxed selection in natural stands to establish foundation populations. Seedling seed orchards can then be established by intensive family and individual-tree selection, or clonal seed orchards can be established from foundation population selections. Emphasis should be on individual-tree selection in the lower Mississippi Valley rather than on selection from favorable stands.

The characters we would emphasize in both initial and subsequent selection are straightness, form class, diameter, height, and small

crown size. Pruning ability, epicormic branching, limb angle, and limb frequency should receive prime consideration in selecting from the foundation population. The stands studied were too dense for extensive epicormic branching, and selecting to minimize this character would be very difficult in natural stands. Rather, we recommend selection of relatively sprout-free families and individuals during preliminary culling of foundation populations. Specific gravity might be considered for improvement, if its economic value warrants it. There is little evidence to suggest that selection for fiber length in sycamore would be worthwhile.

The correlation between height and diameter suggests that it is possible to select for either character and still obtain some gain in the other. We favor selection for diameter, despite the generally higher heritability estimates for height than diameter in both conifers and hardwoods. Diameter growth accounts for most volume and value increment, and it culminates later than height growth. Thus, a relatively modest genetic gain in diameter growth could result in substantial volume and value gains, particularly if there is a concomitant gain in height.

LITERATURE CITED

1. Boyce, S. G., and Kaeiser, M.
   1961. Environmental and genetic variability in the length of fibers of eastern cottonwood. TAPPI 44: 363-366.

2. Dickson, R. E., Hosner, J. F., and Hosley, N. W.
   1965. The effects of four water regimes upon the growth of four bottomland tree species. Forest Sci. 11: 299-305.

3. Echols, R. M.
   1959. The ampliscope—an instrument for wood-fiber measurements. J. Forest. 57: 43-44.

4. Farmer, R. E., Jr., and Wilcox, J. R.
   1966. Specific gravity variation in a lower Mississippi Valley cottonwood population. TAPPI 49: 210-211.

5. Hunter, A. G., and Goggans, J. F.
   1968. Variation in specific gravity, diameter growth, and colored heartwood of sweetgum in Alabama. TAPPI 51: 76-79.

6. Johnson, J. W., and McElwee, R. L.
   1967. Geographic variation in specific gravity and three fiber characteristics . of sweetgum. Ninth South. Conf. on Forest Tree Impr. Proc. 1967: 50-55.

7. Kellison, R. C.
   1967. A geographic variation study of yellow-poplar *(Liriodendron tulipifera* L.) within North Carolina. N. C. State Univ. Sch. Forest. Tech. Rep. 33, 41 pp.

8. McElwee, R. L., and Faircloth, J. B.
   1966. Variation in wood properties of water tupelo in the Southeastern Coastal Plain. TAPPI 49: 538-541.

9. Markwardt, L. J.
   1930. Comparative strength properties of woods grown in the United States. USDA Tech. Bull. 158, 39 pp.

10. Smith, D. M.
    1954. Maximum moisture content method for determining specific gravity of small wood samples. USDA Forest Serv. Forest Prod. Lab. Rep. 2014, 8 pp.

11. Snedecor, G. W.
    1956. Statistical methods applied to experiments in agriculture and biology. Iowa State Coll. Press, Ames. 534 pp.

12. Spurr, S. H., and Hyvärinen, M. J.
    1954. Wood fiber length as related to position in tree and growth. Bot. Rev. 20: 561-575.

13. Thorbjornsen, E.
    1961. Variation in density and fiber length in wood of yellow poplar. TAPPI 44: 192-195.

14. USDA Forest Service.
    1955. Wood handbook. USDA Agr. Handbook 72, 528 pp.

15. Webb, C. D.
    1964. Natural variation in specific grav-

ity, fiber length, and interlocked grain of sweetgum *(Liquidambar styraciflua* L.) in the South Atlantic States. Ph.D. dissertation, Univ. N. C., Raleigh.

16. Wilcox, J. R., and Farmer, R. E., Jr. 1968. Variation in fiber length of eastern cottonwood in the lower Mississippi Valley. TAPPI 51: 574-576.

SOUTHERN FOREST EXPERIMENT STATION

1969

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EXOTIC TREES UNSATISFACTORY FOR FORESTRY IN SOUTHERN ARKANSAS AND NORTHERN LOUISIANA [1]

Hoy C. Grigsby

SOUTHERN FOREST EXPERIMENT STATION

Among 140 species, mainly pine and eucalyptus, the best performers in forest plantings were slash, pond, and Virginia pine, and the longleaf-loblolly cross. None were as large as native loblolly pine after 9 to 12 years in the field, however. A few species showed promise for urban and environmental forestry and for Christmas trees.

Trees of many exotic species have been successfully planted as ornamentals in the Southern United States. For forestry, however, plantings of introduced species have usually been unsatisfactory. This paper reports the performance of nonnative species under plantation conditions in southern Arkansas and northern Louisiana. As in studies in Florida *(1)*, Mississippi *(2)*, and Texas *(3)*, most species failed.

METHODS

Forty-nine pine and 91 other miscellaneous nonnative species were planted on 20 sites with soils ranging from clays to sandy and gravelly loams. Latitude ranged from 32°45′ to 33°45′ N. and longitude from 92°00′ to 93°30′ W. The region's mean annual precipitation of 52 inches is fairly well distributed throughout the year. Growing season rainfall averages 24 inches. The number of frost free days ranges from 220 to 230.

Plantings were made in 25-tree square plots when there was enough trees. Otherwise, plots contained rows of five or 10 trees. When sufficient seedlings were available, plots were replicated 12 times, but seedlings were scarce in many instances. An average of 29 trees were tested on two to three sites. Spacings were 8 by 8 feet and 6 by 10 feet. Cultural treatments were withheld to determine the ability of exotics to withstand natural competition.

RESULTS

Nonnative pines of 18 species survived (table 1). Twelve of these are indigenous to the United States. The most promising were three southern pines, slash *(P. elliottii)*, pond *(P.*

[1] The cooperation of Georgia-Pacific Corporation and Potlatch Forests, Inc., in providing planting sites and assistance in taking measurement data is gratefully acknowledged.

Table 1.—*Surviving species*

Species and origin	Sites planted	Years planted	Trees planted	Survival	Weighted average height [1]
	No.		*No.*	*Percent*	*Feet*
			PINES		
Pinus clausa (Chapm.) Vasey—N. Fla.	14	1955-57	386	2.1	17.5
P. densiflora Sieb. & Zucc.—Japan	3	1955	42	9.5	12.2
P. echinata Mill.—Ark.	18	1955-57	544	27.2	28.0
P. echinata × *P. taeda*—Placerville, Calif.	5	1956-57	50	20.0	30.2
P. echinata × *P. taeda* ×× wind—Placerville, Calif.	1	1954	12	33.3	23.5
P. elliottii var. *densa* Little & Dorman—S. Fla.	6	1954-57	166	1.2	27.0
P. elliottii Engelm.—S. Miss.	15	1954-57	455	29.7	29.1
P. glabra Walt.—S. Miss.	6	1955-56	51	47.1	23.6
P. massoniana Lamb.—China	7	1954-56	105	19.0	13.5
P. nigra Arnold—Italy	16	1955-56	419	.7	7.6
P. palustris Mill.—S. Miss.	17	1954-57	405	15.3	18.6
P. pinaster Ait.—No. 9, No. 10, Italy, France, Morocco, Spain, Portugal	13	1954-57	581	.5	19.3
P. pinea L.—Italy	11	1954-56	133	2.3	8.7
P. ponderosa × *P. montezumae*—Mexico	2	1954-55	7	42.9	16.2
P. pungens Lamb.—N. Ga.	9	1955-57	72	18.1	14.7
P. rigida Mill.—Ga.	1	1954	12	8.3	14.8
P. serotina Michx.—N. Fla.	11	1955-56	121	54.5	28.7
P. ×*sondereggeri* H. H. Chapm.—S. Fla., E. Tex.	16	1954-57	330	38.2	29.4
P. strobus L.—N. C., Ga.	1	1957	24	33.3	7.5
P. taeda L.—Ark.	16	1954-57	582	31.8	33.1
P. taeda ×× *P. echinata* × *P. taeda*—Calif.	1	1957	3	100.0	31.0
P. thunbergiana Franco—Japan	16	1954-57	614	21.0	9.8
P. virginiana Mill.—N. Ala., N. Ga.	13	1954-57	249	52.6	24.9
			MISCELLANEOUS NATIVES AND EXOTICS		
Chamaecyparis thyoides (L.) B.S.P.—N. C.	2	1957	53	35.8	14.6
Cupressus arizonica Greene—S. Ariz.	4	1954-57	84	36.9	13.2
Cupressus sempervirens L.—Italy	2	1954-55	22	4.5	9.0
Cupressus thurifera (*C. lusitanica benthami* Carr.)—Herbst Seed	3	1957	62	1.6	6.0
Cupressus torulosa Don—Himalayas	1	1955	6	33.3	17.1
Juniperus virginiana L.—E. Okla.	11	1956-57	236	26.3	12.5
Populus robusta—S. Europe	2	1957	21	42.9	31.1
Salix nigra Marsh.—Ark.	1	1957	10	20.0	11.5
Taxodium distichum var. *nutans* Ait.—N. Fla.	5	1954-57	94	37.2	4.7
Taxodium distichum var. *distichum*—S. Ark.	8	1954-57	142	40.8	7.3
Thuja japonica—Japan	2	1955-57	9	11.1	3.0
Zelkova serrata Mak.—Calif.	3	1957	93	44.1	14.7

[1] Average height, weighted by age, at the end of the 1966 growing season.

serotina), and the longleaf-loblolly cross *(P.* ×*sondereggeri),* and an Appalachian Mountain-Piedmont species, Virginia pine *(P. virginiana).*

Native loblolly pine *(P. taeda)* was superior to all nonnative species in height growth, but pond, Virginia, spruce *(P. glabra),* and Sonderegger pines excelled it in survival.[2] Three nonnatives grew taller than native shortleaf pine *(P. echinata)* and five survived better. Loblolly outscored shortleaf on both counts. Survival of loblolly and shortleaf was hardly half of that normally expected for these species.

The 12 surviving miscellaneous natives and exotics are also listed in table 1. Four are native to the test area, four are indigenous to the United States, and four are exotic.

[2] Only those sources with 50 or more planted trees were considered in the comparison.

Miscellaneous exotics that showed some promise included *Cupressus arizonica, Zelkova serrata,* and *Chamaecyparis thyoides. C. arizonica* is a Christmas tree species. It grew satisfactorily on several sites and attained salable size in 3 to 5 years. It has been determined that by propagating the best trees by rooted cuttings the proportion of salable *C. arizonica* Christmas trees in a plantation—normally about one in three—can be raised considerably. *Z. serrata* withstands native competition well, is often multistemmed, and is shade tolerant. *C. thyoides* grows well on wet sites, is more tolerant to competition than the southern pines, and will undoubtedly grow at a closer spacing than the pines.

Only 11 *Cryptomeria japonica* were tested. Although all of these were winter-killed, a single tree in a demonstration plot survived. It is well developed and fast growing, but the new growth is occasionally killed by low winter temperatures. Visitors from the Orient report that *C. japonica* does well in areas of Japan where winters are much colder than any encountered in the present study. Strains from those areas may perform well here.

Soil textures on which some of the species survived best are given in table 2. Several species survived equally well on three or four soils, but most did best on fine sandy loams. Next best survival was obtained on silty clay loams and clays. In general silty clay loams or coarser textures were best.

Thirty-two pine and 79 other species failed in the trials. Sixteen of the unsatisfactory pines are nonnative to the test area but are indigenous to the United States. The others are native to Mexico, Central America, the Caribbean, Europe, and Asia. Failure of all 46 eucalyptus species was caused mainly by winter kill either in the nursery or during the first year in the plantation. The species that failed, along with their geographic seed sources, are listed at the end of this note.

DISCUSSION

Complete failures of species were probably due to weed and grass competition and unfavorable temperature, humidity, and rainfall. As expected, most mortality occurred during the year of outplanting.

The effects of weather on survival of promising species were unclear. Survival was generally highest in 1954, when annual rainfall was lowest and summer temperatures were highest (table 3). During August 1954, there were 18 consecutive days with a maximum temperature of 100°F. or more. Survival was poorest in 1957, when annual rainfall was considerably above average and summer temperatures were below average. That year was the only one in which growing-season rainfall departed radi-

Table 2.—*Survival in relation to soils*

Species	Soil textures on which survival was best								
	Clay	Silty clay	Clay loam	Silty clay loam	Silt loam	Fine sandy loam	Sandy loam	Fine sand	Gravelly loam
Pinus clausa (Chapm.) Vasey						x			
P. echinata Mill.	x					x			x
P. elliottii Engelm.				x					
P. elliottii densa Little & Dorman						x			
P. nigra Arnold						x			
P. palustris Mill.				x					
P. pinaster Ait.								x	
P. pinea L.		x				x			
P. pungens Lamb.					x	x			
P. serotina Michx.	x			x		x			
P. ×sondereggeri H. H. Chapm.				x	x			x	
P. taeda L.	x				x		x	x	
P. thunbergiana Franco						x			
P. virginiana Mill.						x	x		x
Juniperus virginiana L.	x			x		x			
Taxodium distichum var. *nutans* Ait.	x								
Taxodium distichum var. *distichum*	x			x					

Table 3.—*Rainfall and temperatures, 1954-1957*

Year	Rainfall				Temperature	
	April-September		Total for year			
	Actual	Departure	Actual	Departure	Maximum	Minimum
	Inches				°F.	
1954	20.25	−2.81	38.09	−12.72	108	16
1955	20.87	−2.19	47.66	−3.15	98	12
1956	19.38	−3.68	47.23	−3.58	104	16
1957	37.47	+14.41	74.52	+23.71	97	13

cally from normal—plus 14.41 inches. Although many of the successful nonnatives are from areas south of the plantations, it seems unlikely that dry, hot weather in the summer directly improved the survival of newly planted seedlings. Perhaps heavy rains during the growing season decreased survival indirectly by increasing weed and grass competition.

Winter cold caused many failures. The minimum temperature during the study was —3°, but only three times did winter temperature drop below 11°.

Most of the pines, except slash and longleaf, were attacked by the Nantucket pine tip moth *(Rhyacionia frustrana* Comst.). Slash, Sonderegger, loblolly, and pond pines were attacked by fusiform rust *(Cronartium fusiforme* Hedgc. and Hunt ex Cumm.). With the exception of a small amount of gall rust *(C. cerebrum* Hedgc. and Long), no other diseases were observed on shortleaf pine.

LITERATURE CITED

1. Kraus, J. F.
   1963. The Olustee Arboretum—performance of 67 species of forest trees. USDA Forest Serv. Res. Pap. SE-4, 47 pp. Southeast. Forest Exp. Sta., Asheville, N. C.

2. Schmitt, D., and Namkoong, G.
   1965. Pine species in the Harrison Experimental Forest Arboretum. USDA Forest Serv. Res. Pap. SO-18, 18 pp. South. Forest Exp. Sta., New Orleans, La.

3. Zobel, B. J., Campbell, T. E., Cech, F. C., and Goddard, R. E.
   1956. Progress report—survival and growth of native and exotic pines, including hybrid pines, in western Louisiana and east Texas. Tex. Forest Serv. Res. Note 17, 16 pp.

SPECIES THAT FAILED AND THEIR SEED SOURCES

PINES

Pinus attenuata Lemm. ..... Calif.
P. attenuata × *P. radiata* ..... Calif.
P. bahamensis (P. caribaea) ..... Bahamas
P. banksiana Lamb. ..... Minn.

P. caribaea Morelet ..... Br. Honduras
P. coulteri D. Don ..... Calif.
P. elliottii × *P. palustris* ..... Gulf South
P. excelsa (P. griffithii) Wall. ..... Himalayas
P. griffithii McClelland ..... Himalayas
P. halepensis Mill. ..... Italy

P. hondurensis (P. caribaea) ..... Br. Honduras
P. jeffreyi Grev. & Balf. ..... Calif.
P. khasya Royle ..... Burma
P. lambertiana Dougl. ..... Calif.
P. longifolia (P. roxburghii Sarg.) ..... India
P. luchuensis Mayr ..... Okinawa
P. lumholtzii Robins. & Fern. ..... Mexico

P. merkusii Jungh. & de Vriese ..... Burma
P. michoacana Martinez ..... Mexico
P. montezumae Lamb. ..... Mexico
P. muricata D. Don ..... Calif.
P. patula Schiede & Deppe ..... Mexico

P. ponderosa Laws. ..... Ariz., Calif.
P. ponderosa var. *arizonica* (Engelm.) Shaw ..... Ariz.
P. ponderosa × *P. engelmannii* ..... Calif.
P. pseudostrobus Lindl. ..... Mexico
P. radiata D. Don ..... Calif.
P. reflexa Engelm. *(P. strobiformis)* ..... Mexico

P. sabiniana Dougl. ..... Calif.
P. sylvestris L. ..... Spain
P. taeda L. ..... Tex.
P. teocote Schiede & Deppe ..... Mexico
P. torreyana Parry ..... Calif.

Ailanthus glandulosa Desf. ..... Herbst Seed
Araucaria angustifolia (Bert.) O. Kuntze ..... Brazil
Callitris calcarata A. Cunn. ex Mirb. ..... Australia
C. robusta R. Br. ..... Australia
Casuarina cunninghamia Miq. ..... Ark.
C. equisetifolia Forst. ..... Australia
C. spp. Forst. ..... Herbst Seed
Cedrus atlantica Manetti ..... Morocco
Cryptomeria japonica (L. f.) D. Don ..... Taiwan
Cunninghamia lanceolata (Lamb.) Hook. ..... Taiwan

Cupressus funebris Endl. ..... China
C. lusitanica Mill. ..... Mexico
C. macnabiana A. Murr. ..... Calif.
C. macrocarpa Hartw. ..... Calif.
Eucalyptus alba Reinw. ..... Australia

E. andrewsi Maiden ..... Australia
E. astringens Maiden ..... Australia
E. bicostata Maiden Blakely & Simmonds ..... Australia
E. botryoides Sm. ..... Brazil
E. bridgesiana R. T. Baker ..... Australia

E. calophylla Lindl. ..... Australia
E. camaldulensis Dehn. ..... Brazil
E. cinerea F. v. M. ..... Australia
E. citriodora Hook. ..... Australia
E. considiniana ..... Australia

E. cornuta Labill ..... Australia
E. crebra F. v. M. ..... Australia
E. dalrympleana Maiden ..... Australia
E. diversicolor F. v. M. ..... Australia
E. fastigata Deane & Maiden ..... Australia

E. ficifolia F. v. M. ..... France
E. globulus Labill ..... Australia via Calif.
E. gomphocephala A. DC. ..... Australia
E. grandis Hill ex Maiden ..... Brazil
E. gunni Hook. f. ..... Australia

E. haemastoma Sm. ..... Australia
E. macarthuri Deane & Maiden ..... Australia
E. macrorrhyncha F. v. M. ..... Australia
E. maculata Hook. ..... France
E. melanophloia F. v. M. ..... France
E. melliodora A. Cunn. ..... Australia
E. nitens Maiden ..... Australia
E. paniculata Sm. ..... Brazil, France
E. paulistana ..... Brazil

E. pilularis Sm. ..... Australia
E. polyanthema × *populifolia* ..... France
E. populifolia Hook. f. ..... France
E. propinqua Deane & Maiden ..... Brazil
E. punctata DC. ..... Australia

E. racemosa crebra ..... Brazil
E. radiata Sieb. ex DC. ..... Australia
E. resinifera Sm. ..... Brazil
E. robusta Sm. ..... Australia
E. rostrata Schlechtend ..... France

E. saligna Sm. ..... Brazil
E. siderophloia Benth. ..... Australia
E. sideroxylon A. Cunn. ex Benth. partim. Australia
E. triantha acmenioides Link. ..... Brazil
E. umbra R. T. Baker ..... Brazil

E. viminalis Labill. ..... Brazil
Ginkgo biloba L. ..... Japan
Grevillea robusta A. Cunn. ..... Australia
Koelreuteria spp. ..... China
Leucaena glauca (L.) Benth. ..... Taiwan

Libocedrus decurrens Torr. ..... Calif.
Liriodendron tulipifera L. ..... Ark.
Melia azedarach L. ..... La.
Phellodendron amurense ..... Orient
P. spp ..... Orient

Phyllocladus trichomanoides ..... New Zealand
Phyllostachys bambusoides ..... Japan
Platanus occidentalis L. ..... Ark.
Populus heterophylla L. ..... Miss. River Delta
Pseudolarix kaempferi ..... China

Pseudotsuga macrocarpa Mayr ..... Calif.
P. taxifolia (Pori.) Britt ..... Calif.
Pterocarya spp. ..... Japan
Sequoia sempervirens (Lamb.) Endl. ..... Calif.
Tamarix aphylla (L.) Karst. ..... Unknown

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CONVERTING DENDROMETER ESTIMATES OF OUTSIDE-BARK STEM DIAMETERS TO WOOD DIAMETERS ON MAJOR SOUTHERN PINES

Clement Mesavage [1]

Because the pattern of DIB/DOB ratios up the stem may be a species characteristic, Grosenbaugh's STX computer program for processing tree measurements provides three options in which DBHIB/DBHOB is assumed to stay constant or to curve hyperbolically for either diminishing or increasing relative bark thickness. Measurements of felled shortleaf, loblolly, longleaf, and slash pines show that bark thickness for these species diminishes up the stem and can be predicted adequately by the corresponding STX option.

Several procedures may be applied to correct for bark thickness when dendrometers are used for measuring sample trees. Sometimes it may suffice to compile the entire estimate in terms of outside-bark volume and convert the total in one operation. Similarly, total volume of individual trees may be converted by appropriate inside bark/outside bark correction factors. However, the full utility of dendrometry cannot be realized unless each stem diameter defined by the dendrometer is converted separately. This procedure, feasible with computers even when complex correction equations are required, affords the greatest flexibility for stating cruise estimates in terms of net product units or values for any portion of a total estimate.

Bark thickness frequently varies considerably among trees of the same species and size. For a given tree, however, its relationship to stem diameter at various points can often be predicted from measurement of a reference bark thickness at a single point on the bole. Breast height is a convenient reference point, and if the reference bark thickness is expressed as the ratio of DBHIB/DBHOB, the function can be used to convert DOB to DIB at any other point above or below DBH.

There is considerable evidence that the relationship of DBHIB/DBHOB to DIB/DOB at other points on a tree is a species characteris-

[1] The author is Forester, Division of Timber Management, National Forest System, USDA Forest Service. The research described here was accomplished in good part while he was on the staff of the Southern Forest Experiment Station, USDA Forest Service, at Harrison, Arkansas.

tic. Meyer *(3)* reported that the two relationships are equivalent for chinchona in Latin America, as well as for hemlock, white pine, white oak, red oak, black oak, scarlet oak, and red maple in Pennsylvania. Pemberton *(4)* found that on redwood the ratio increases "at a fairly regular rate" with distance up the tree. In what may be the only reported study of bark thickness aimed at computer-correction of dendrometer measurements, Johnson *(2)* found that the ratio increases curvilinearly for young Douglas-fir. In exploratory work in Arkansas, the author found indications that the ratio increases curvilinearly for shortleaf and loblolly pines, decreases curvilinearly for white oak, and is constant for blackgum.

Grosenbaugh *(1)* was faced with this plethora of patterns when he prepared the STX—FORTRAN 4 program for processing tree measurements. He decided to program three options by which DBHIB/DBHOB could be altered so that the ratio would remain constant, increase curvilinearly, or diminish curvilinearly—the choice to be made by the program user. For those discontented with these options, he arranged a junction point in the program for user-supplied subroutines.

In the study reported here the purpose was to learn which of the programmed options is most applicable for the major southern pines.

Alternative formulae in the STX program are:

Option 1. DIB/DOB at any point on a stem is assumed equal to (DBHIB/DBHOB). DIB = DOB (DBHIB/DBHOB).

Option 2. DIB/DOB is projected hyperbolically. DIB = DOB (1.0 — (1.0 — DBHIB/DBHOB) (QUAN/(DENO — DOB/DBHOB))). QUAN and DENO establish the asymptotes of the curve and are readily changed in the STX program. In the present program, QUAN = 1.0, and DENO = 2.0. With this equation, DIB/DOB increases above DBH and decreases below DBH, i. e., relative bark thickness diminishes up the stem.

Option 3. DIB/DOB is projected hyperbolically. DIB = DOB (DBHIB/DBHOB) (QUAN/(DENO —DOB/DBHOB)). QUAN = 9.0 and DENO = 10.0. With this equation, DIB/DOB decreases above DBH and increases below DBH, i. e., relative bark thickness increases up the stem.

Curvature in the formulae is introduced by the modifier (QUAN/(DENO — DOB/DBHOB)), in which the function DOB/DBHOB = 0.0 at tree tip, 1.0 at breast height, and more than 1.0 at stump height. DIB/DOB varies in the same direction as DBHIB/DBHOB and in the opposite direction from (1.0 — DBHIB/DBHOB).

THE DATA

Sample trees were selected to obtain a range in sizes for the major southern pine species. They included 79 shortleaf *(Pinus echinata* Mill.), 32 loblolly *(P. taeda* L.), 17 longleaf *(P. palustris* Mill.), and 15 slash *(P. elliottii* Engelm.) pines.

The trees were felled and stems were measured at the stump, at 2-foot intervals to 8 feet above the stump, and then at 8-foot intervals to a pulpwood top of about 4 inches OB. In addition, measurements were made at points marking the base of the live crown and the sawtimber top. The stem measurements included total height, log length, and taped OB stem diameters (to 0.1 inch). Average bark thickness was obtained from Swedish bark gage measurements at four places around the stem. Inside-bark diameters were derived by subtracting double bark thickness from taped DOB.

Cubic-foot volumes were computed from measured DOB and DIB, and from estimated DIB derived by the three STX formulae.

RESULTS

Option 2 resulted in more accurate volume estimates for southern pines than any of the alternatives. For estimating total volume, the equation was —2.5 percent for loblolly, —0.9 percent for pulpwood-size shortleaf, —0.6 for slash, +0.4 for longleaf, and +0.5 for sawtimber-size shortleaf. For estimating sawtimber volume, the equation was —2.8 percent for loblolly, —2.2 for slash, —0.5 for longleaf, and —0.4 for shortleaf. Accuracy was best for the stem portions having the greatest value, i. e., the clear stem from stump to base of the live crown. Accuracy was poorest for the portion from pulpwood top to tree tip.

The pattern of bark thickness behavior for southern pines is graphed in figure 1. Meas-

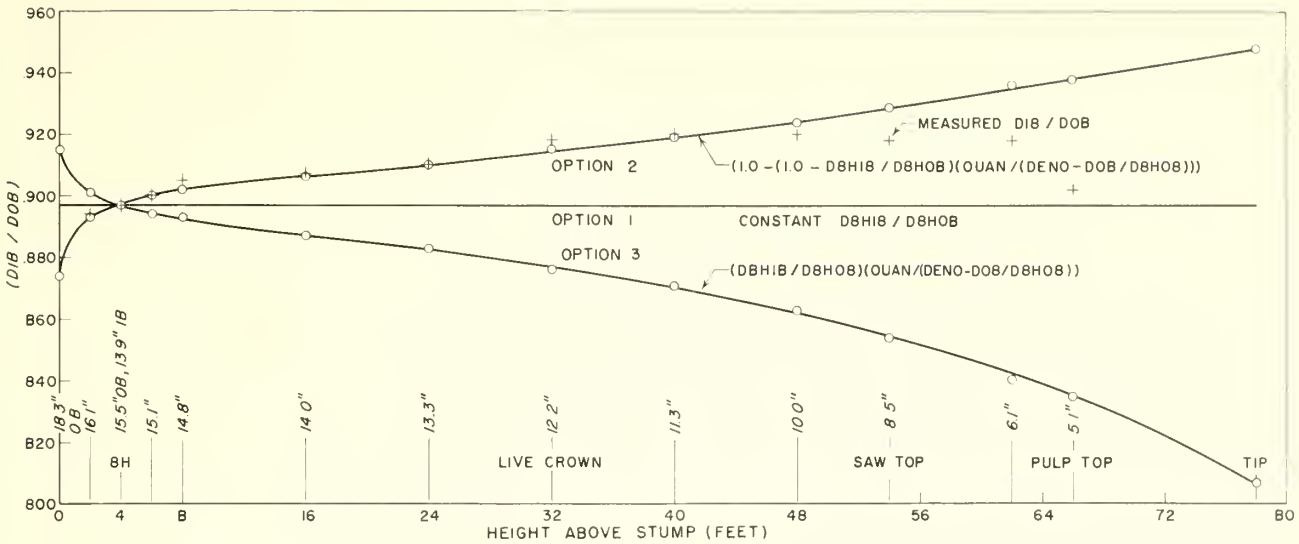

Figure 1.—*Relation of DIB/DOB to stem height. Option 1 assumes a constant relationship equivalent to DIB/DOB at breast height. Option 2 assumes a curvilinear relationship in which bark thickness diminishes above DBH and increases below DBH. Option 3 also assumes a curvilinear relationship, but bark-thickness trend is opposite to that of Option 2. Rates of curvilinear ascent or descent are controlled by changing values of QUAN and DENO in the formulae.*

Plotted measurements for one of the sample trees follow the curve for Option 2 throughout the important portion of the tree stem. All other individual southern pine samples measured in this study exhibited the same trend.

ured values of DIB/DOB for one of the sample trees are plotted on the figure for a direct comparison with formulae-derived relationships. The measured values fell on or near the Option 2 curve throughout the important portion of the tree stem. All other individual sample trees exhibited the same pattern. Option 2 underestimated bark thickness above the sawtimber top, the bias increasing towards the tree tip.

This bark pattern is also shown by table 1, in which volumes of shortleaf sawtimber trees predicted by Option 2 are compared with measured volumes, by tree section. Both bias and variability increased above the sawtimber top. The increase was particularly rapid above the pulpwood top, but the equation was accurate and precise for the sawtimber portion.

More or less slope in the calculated curves can be obtained by changing the magnitude of QUAN and DENO in the STX formulae. The value of DENO — QUAN, should, however, be equal to 1, in order that measured DBHIB/DBHOB will equal the calculated value of DIB/DOB at breast height.

Table 1.—*Relationship and variability of predicted (Option 2) and measured sawtimber volumes, shortleaf pine, by tree section*[1]

Tree section	Average per tree: predicted/measured	Coefficient of variation
		Percent
8-ft. butt log	0.993	± 2.5
8-ft. above stump to base of live crown	.982	± 2.9
Base of live crown to sawtimber top	1.026	± 3.2
Sawtimber top to pulpwood top	1.072	± 5.3
Pulpwood top to top	1.166	± 11.3

[1] Basis: 54 of the 79 measured shortleaf pines.

Although the STX program has a tie point for user-supplied bark correction equations, the optioned formulae, with QUAN and DENO modified if necessary, should be tried first even for species other than southern pines. Any alternative equation is likely to require multivariate regression analyses that may be tedious and costly, with little assurance of improved accuracy.

LITERATURE CITED

1. Grosenbaugh, L. R.
   1964. STX—FORTRAN 4 program for estimates of tree populations from 3P sample-tree-measurements. USDA Forest Serv. Res. Pap. PSW-13, 49 pp. Pacific Southwest Forest and Range Exp. Sta., Berkeley, Calif.
2. Johnson, F. A.
   1966. Bark factors for Douglas-fir. USDA Forest Serv. Res. Note PNW-34, 3 pp. Pacific Northwest Forest and Range Exp. Sta., Portland, Oreg.
3. Meyer, H. A.
   1946. Bark volume determination in trees. J. Forest. 44: 1067-1070.
4. Pemberton, J. E., Jr.
   1924. The relation of bark to diameter and volume in redwood. J. Forest. 22: 44-48.

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1969

U.S. FOREST SERVICE RESEARCH NOTE

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REPRODUCTIVE MATURITY RELATED TO HEIGHT OF LOBLOLLY PINE

Ronald C. Schmidtling

SOUTHERN FOREST EXPERIMENT STATION

In a Pinus taeda *L. plantation in which plots were cultivated, fertilized, or both, initial flowering was closely related to tree height. Height at flowering age did not differ among cultural treatments that greatly influenced growth rates.*

Several theories have been advanced to explain lack of flowering by young woody plants of some species. In his experiments with fruit trees, Knight *(3)* observed that: "When young trees have sprung from seed, a certain period of time must elapse before they become capable of bearing fruit, and this period, I believe, cannot be shortened by any means." Fritsche *(1)* agreed that time is the key factor. But Longman and Wareing *(4)* suggested that size is critical, and Schaffalitzky de Muckadell *(5)* stated that "growth vigour, as affected by environment, may be just as important a factor to determine meristematic aging as the actual number of preceding shoot generations."

I have observed that the first trees to flower at a given age are among the largest and most vigorous, and an ideal opportunity to study the importance of size to reproductive maturity was presented in a young experimental plantation of loblolly pine *(Pinus taeda* L.) which was designed to test the effects of cultivation and fertilization on growth *(6)*. Five different treatments were applied in the plantation: control, cultivated only, and cultivated plus three levels of fertilization. The fertilizer was applied at the beginning of the second growing season, and cultivation was carried out the first 3 years. Four 200-tree plots of each treatment were included in the plantation which contained a total of 4,000 trees.

The cultural treatments greatly improved height growth of trees during their first 4 years in the field. Cultivation alone increased height growth, and fertilization in addition to cultivation caused further increases *(6)*.

Flowering response (the production of female strobili) to the cultural treatments closely paralleled height-growth response (fig. 1). The number of trees that had flowered by the fourth

year was increased by cultivation, and further increased by cultivation plus fertilization. Neither height growth nor flowering were influenced by adding amounts of fertilizer greater than the minimum, 100 pounds of N, 50 pounds of P, and 50 pounds of K per acre.

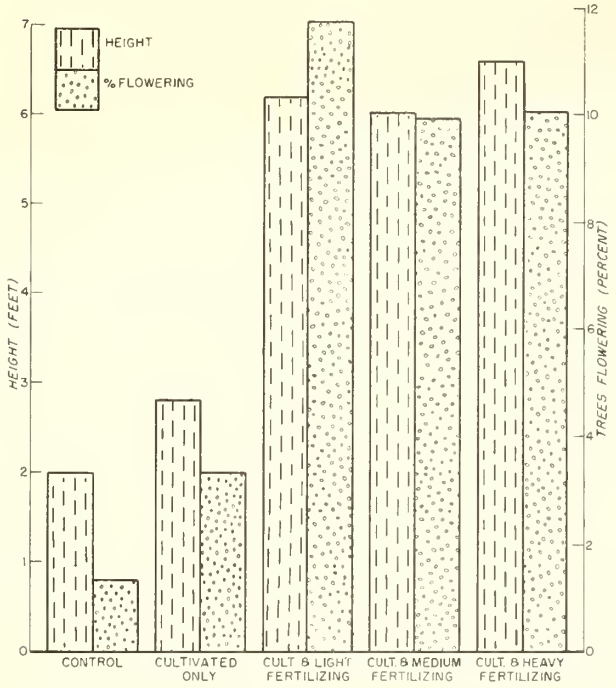

Figure 1.—*Effects of cultural treatments on height and cumulative flowering of loblolly pines after 4 years in the field. Light fertilizing was 100 pounds N, 50 pounds P, and 50 pounds K per acre. Medium application was twice and heavy was four times the light application.*

The relations between minimum height and reproductive maturity were compared on fertilized and unfertilized plots. Only the first trees to flower in each plot were considered, because there appears to be considerable genetic variation in precocious flowering in loblolly pines—many trees which would otherwise be expected to flower do not *(2)*. Such trees may flower late and cause an overestimate of minimum flowering size.

The trees that flowered in the first 4 years on the fertilized plots and in the first 5 years on the unfertilized plots were included in the analysis. Approximately 2 percent of the trees from each group, a total of 91, were considered.

The average heights at the time of first flowering were 5.9 feet for the fertilized plots, and 5.3 feet for the unfertilized plots. The difference was not statistically significant. In spite of the large differences in growth rates, in fertility of the sites, and in the age at which flowering occurred, minimum height for flowering was not influenced by treatment.

The results support the view that size is more important than age in determining reproductive maturity. It seems reasonable to assume, therefore, that treatments which increase growth of young trees also will cause early flowering.

LITERATURE CITED

1. Fritsche, R.
   1948. Untersuchungen über die Jugendformen des Apfel- und Birnbaumes und ihre Konsequenzen für die Unterlagen- und Sortenzüchtung. Ber. schweiz. bot. Ges. 58: 207-267.

2. Greene, J. T.
   1967. Cone and seed yields from F_1 crosses involving five and six year old and controlled-pollinated seedlings of loblolly pines. Ninth South. Forest Tree Impr. Conf. Proc. 1967: 111-114.

3. Knight, T. A.
   1820. Observations on the method of producing new and early fruits. Hort. Soc. London Trans. 1: 30-40.

4. Longman, K. A., and Wareing, P. F.
   1959. Early induction of flowering in birch seedlings. Nature 184: 2037-2038.

5. Schaffalitzky de Muckadell, M.
   1959. Investigations on aging of apical meristems in woody plants and its importance in silviculture. Danish Forest Exp. Sta. 25: 307-455.

6. Smith, L. F., and Schmidtling, R. C.
   1969. Cultivation and fertilization speed early growth of planted southern pines. USDA Forest Serv. Tree Planters' Notes 20(3) (In press).

SOUTHERN FOREST EXPERIMENT STATION

1969

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MODIFICATION OF A ZEISS TELEMETER TELETOP FOR PRECISION DENDROMETRY

Clement Mesavage [1] [2]

The optical system of a Zeiss Telemeter Teletop was modified to form the prototype of a magnifying dendrometer with coincident split images for measuring distance, height, and diameter. For measuring distance, it employs a fixed parallactic angle and a variable base. Vertical angles are measured with a hypsometer graduated to 0.1°. The instrument functions as an optical caliper for diameters within the length of the measuring scale, and as an optical fork with a variable parallactic angle and variable base for measuring diameters that exceed scale-length.

THE ZEISS TELETOP

The topographical telemeter Teletop [3] was developed prior to World War II by VEB Carl Zeiss, Jena, east Germany, for making distance, height, and direction measurements needed in surveying inaccessible locations, and for measuring diameters of tree trunks. Its use for dendrometry was reported by Ruden [4] in 1939 but attracted little attention otherwise until H. P. Fricke of the Royal College of Forestry, Stockholm, Sweden, incorporated its optical system into an instrument called the Universal Teledendrometer, or UTD. The UTD is manufactured by J. Berg, Stockholm.[5]

The Teletop, shown in figure 1, consists of a mounting bracket with a leveling base and circular level, main and tilting axes, vertical circle, card-type compass, and optical system. The optical system is detachable; it is mounted on a rail to which are affixed two scales. One of the scales, on the face of the rail, is for diameter measurement; the other, on the edge of the rail, is for distance measurement. The scales are graduated in centimeters and meters, but may also be obtained in inches and feet.

Two pentaprisms and a 6× telescope form the principal parts of the optical system. One pentaprism and the telescope are attached

[1] The author is Forester, Division of Timber Management, National Forest System, USDA Forest Serv.

[2] Acknowledgment is made of assistance and advice, particularly from David Bruce, Pacific Northwest Forest and Range Exp. Sta., USDA Forest Serv.; and also from Dr. T. N. Moss, optometrist at Harrison, Ark.; Ake Wiksten, Dep. Forestry Ottawa, Can.; the Dietzgen Co., Chicago, Ill.; and the American Optical Co., Buffalo, N. Y.

[3] Imported in United States by Zena Co., 723 22nd St., Union City, N. J. 07087.

[4] Ruden, T. Landmålerinstrumentet "Teletop." Skogbrukerer 16: 262, 264-265. 1939.

[5] Imported in United States by Forestry Suppliers, Inc., 205 W. Rankin St., Jackson, Miss. 39204.

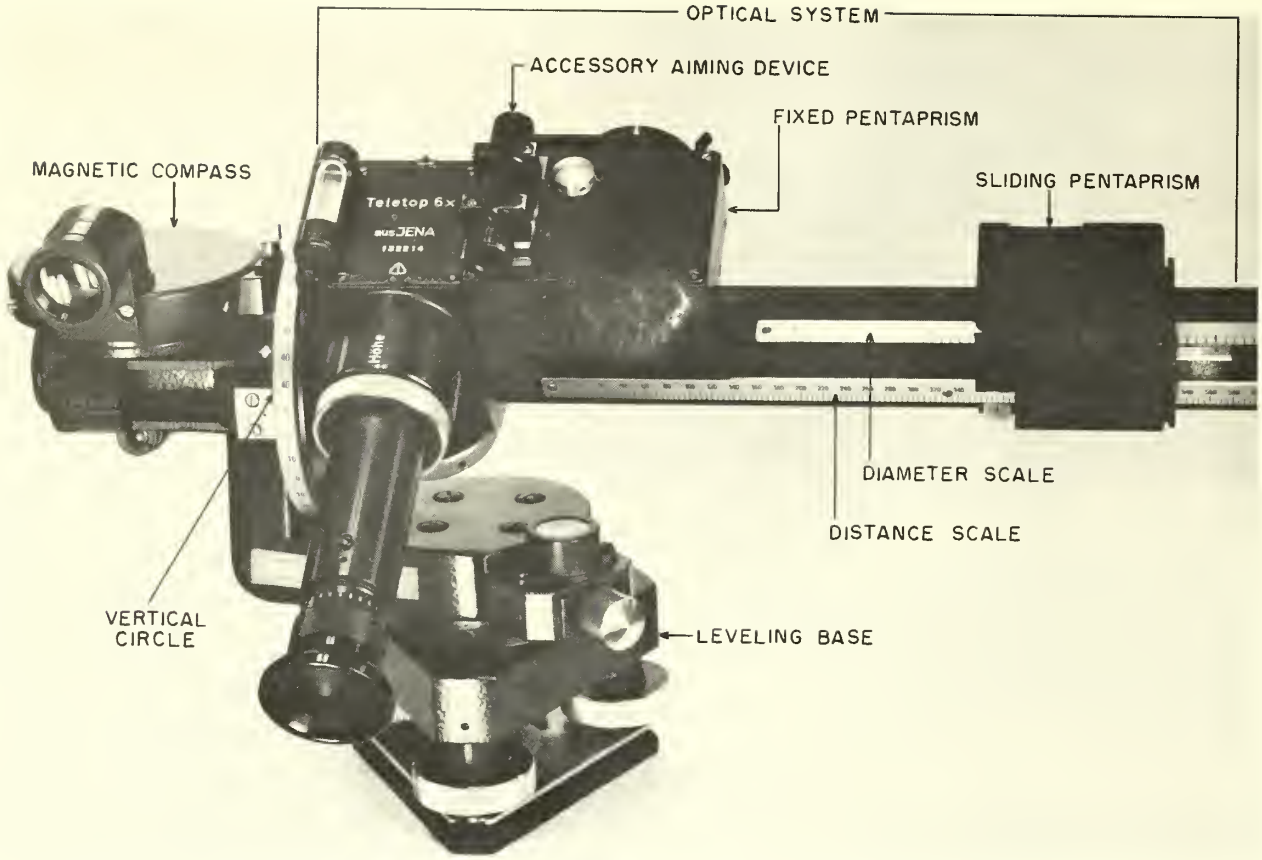

Figure 1.—*Zeiss Teletop.*

firmly to the rail and the other prism slides on the rail. Well-defined split images of lines of sight reflected by the prisms are collected on the image plane of the telescope. The images are inverted if the telescope is mounted horizontally, as in figure 1. When the telescope is positioned vertically the images are erect, though mirrored, for observations made from the side of the instrument.

In determining distance, a circular wedge prism is inserted in front of the fixed pentaprism to deflect the line of sight, and the other pentaprism is shifted to obtain an intersecting line of sight, as shown by figure 2. Intersection is accomplished when the half pictures are in true coincidence, as shown by figure 3. Distance to a target is proportional to the amount of image displacement. With a 1-diopter prism, the ratio of base length to distance is 1:100; therefore 1 inch of image displacement represents 100 inches, or 8.3 feet of distance. A 12-inch scale attached to one edge of the rail has a capacity for measuring approximately 100 feet. Prisms are also available for ratios by which distance can be extended to 250, 500, 1,000, or 2,000 feet.

Diameters may be measured in two ways. Without the deflecting prism, the instrument serves as an optical caliper for diameters within the capacity of the measuring rail—approximately 12 inches and smaller. The user pushes the movable prism out until the half pictures are aligned for "false coincidence," as shown by figure 3, and then reads diameter from a scale attached to the face of the rail.

With the 1-diopter deflecting prism inserted in front of the fixed pentaprism, the instrument serves as a variable-base optical fork that extends the diameter range to 24 inches, i. e., twice the length of the rail scale. Two measurements of image displacement are required, and these are added. The first is made with the images in true coincidence. For the second reading, the deflecting prism is rotated 180°, and the movable pentaprism is shifted to achieve false coincidence. The housing of

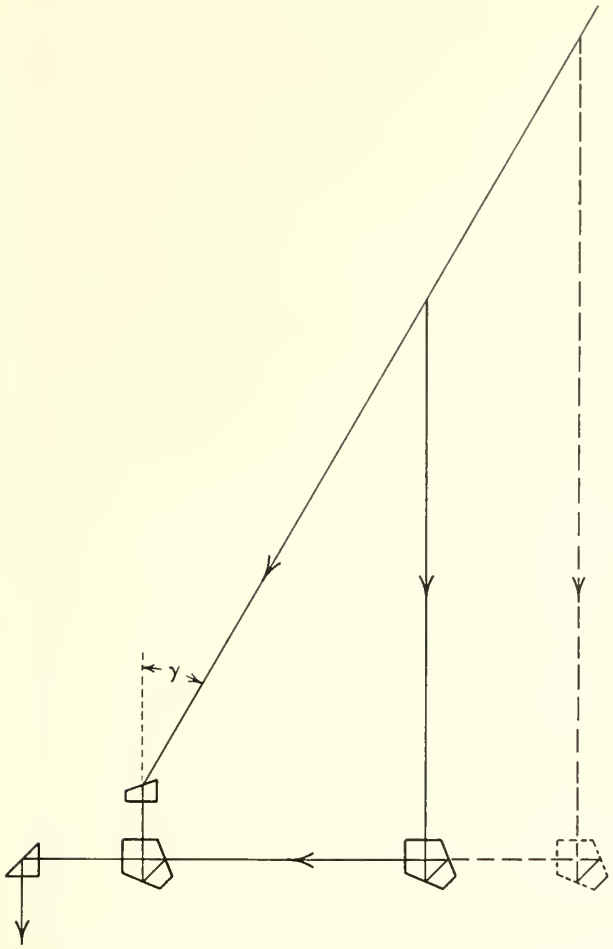

Figure 2.—*Base length, measured on the instrument scale, is proportional to the distance at which the deflected and perpendicular lines of sight intersect.*

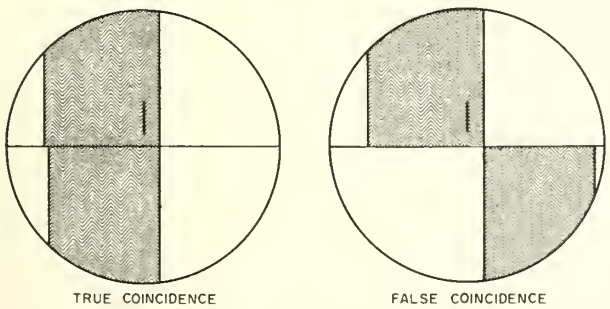

Figure 3.—*Image alignment for true and false coincidence. Images are inverted when telescope is mounted horizontally. They are erect, though mirrored, when telescope is mounted in an upright position and observer is at the side of the instrument. The halving-line must be oriented square across the tree section at the point of measurement, and the vertical reference line (etched on the fixed pentaprism) must be near the line of coincidence.*

the deflecting prism is marked to indicate correct orientation for true and false deflection.

To measure vertical angles, the instrument must be leveled. Angles of elevation and depression may then be read from a vertical circle graduated in degrees. Height above or below horizontal is computed by multiplying the sine of the angle by the slant distance.

THE UNIVERSAL TELEDENDROMETER

The primary difference between the Teletop and the Universal Teledendrometer is in the way tree height is measured. With the UTD, height is measured directly with a system of steel scales that reproduce angles and distances to the base and upper points on a tree stem. As shown by figure 4, the optical system of the Teletop is mounted (detachably) with this vertical scale assembly, and serves, as explained previously, for measuring diameter and distance. Since the telescope is mounted horizontally, the image is inverted. The deflecting prism is hinge-mounted for convenience in use and as protection against loss.

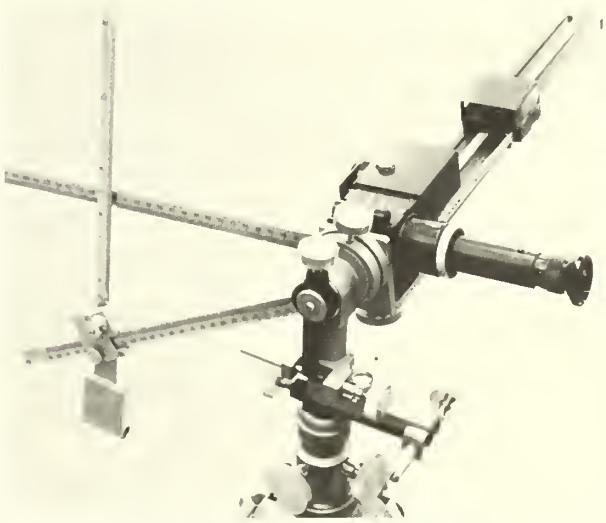

Figure 4.—*The Universal Teledendrometer. The Teletop incorporated by this instrument is made by Zeiss/Jena.*

LIMITATIONS OF THE TELETOP AND TELEDENDROMETER

Neither the Teletop nor the Teledendrometer is adapted well for dendrometry when the instruments must be carried about, especially on brushy, rough terrain. Their bulk and weight are disadvantageous, and serious difficulties

arise in measuring trees that have diameters greater than the length of the scale, because distance is a function in such measurements. For example, when true coincidence is established with a 1-diopter prism at a distance of 40 feet, the first reading of the diameter scale is 4.8 inches. Since the second reading (with false coincidence) is limited by scale capacity, the maximum diameter that can be measured at this distance is 4.8 + 12.0 = 16.8 inches. To measure a diameter of 20 inches, the instruments must similarly be set up at least 66.7 feet away, and for 23 inches, at least 91.7 feet away. Since no distance can be measured beyond 100 feet (with the 1-diopter prism and 12-inch rail scale furnished), it is obvious that the range of radii in which the instruments can be set up diminishes as diameters increase, and much effort can be wasted in finding acceptable locations and clearing lines of sight.

IMPROVEMENT OF THE TELETOP FOR DENDROMETRY

Figure 5 shows the prototype of a Teletop modification designed by the author. The design sacrifices utility of the instrument for surveying to improve its performance for dendrometry. The modification retains the precision of the parent instrument for measuring distance and diameter, simplifies its use for measuring height, increases measurement range and portability, and permits measurement of all diameters within its capacity at practically any working distance. It is hoped that factory-altered instruments incorporating these changes will be available in the near future.

The distance-diameter dilemma was eliminated by making it possible to measure diameter independently of distance. This was done by using an assembly of counter-rotating prisms, instead of the 1-diopter prism furnished with the Teletop, to permit changing prismatic power as needed for achieving true coincidence of the images at practically any distance. The operator may consequently adjust the instrument to a desirable location, rather than change locations to accommodate the instrument.

Several additional changes were made to increase capacity and flexibility:

1. A new measuring rail was made to extend the scale to 18 inches. This rail increases

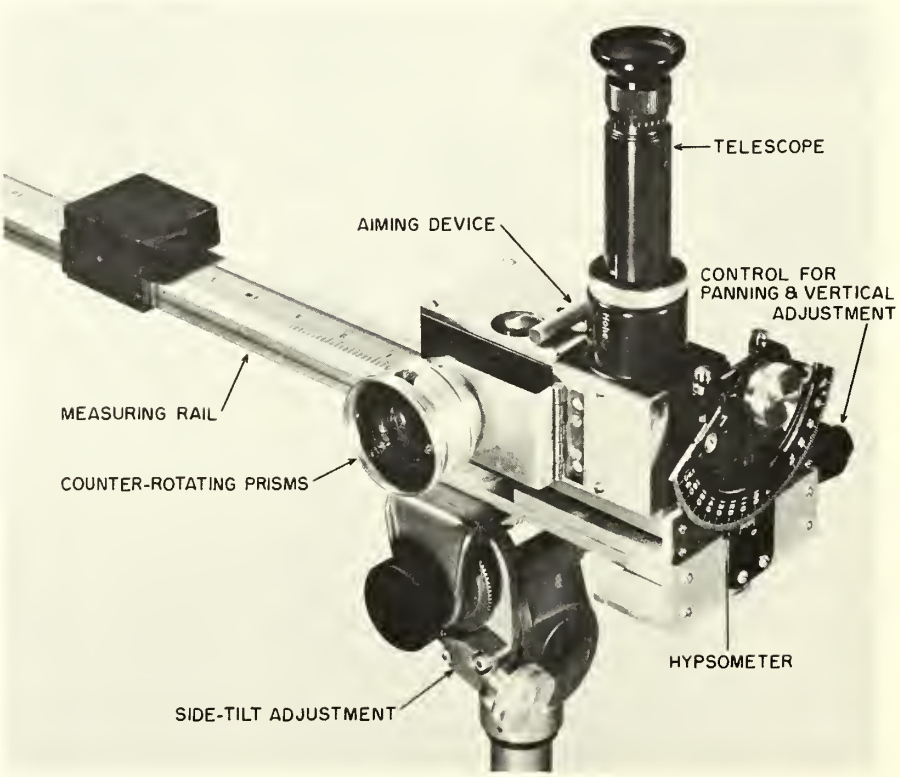

Figure 5.—*Prototype of modified Teletop.*

diameter capacity to 36 inches, without further instrument refinements. With further refinements, discussed below, capacity can be increased to 54 inches.

2. The counter-rotating prism was fitted with a stop for presetting the prisms at 0.833 diopter for use in measuring distance. With this prismatic power, the ratio of base length to distance is 1:120. Consequently, the scale for measuring diameter in inches serves also to measure distance in feet. The 18-inch scale has a slant-distance capacity of 180 feet.

3. An arc-vial assembly from an Abney hand level was fitted with an engraved scale and a vernier for readings of vertical angles to 0.1°. To eliminate negative angles, the scale was graduated to read in terms of (degrees + 100), with a swing of ±60°. The assembly does not add appreciably to either weight or bulk, and the instrument base does not have to be leveled for its use.

4. A collimating sight was mounted for rapid aiming of lines of sight.

5. The telescope was positioned vertically, rather than horizontally, in order to obtain an erect image. Although right and left sides of the image are transposed, i. e., the image is mirrored, vertical positioning is preferable because an erect image facilitates sighting through foliage. Downward viewing is free of sky-glare, and extreme vertical swings can be made without operator discomfort.

If the telescope is leveled (a swing of 90°), the view is directly upwards for measuring distance to overhead points, such as height to base of a tree crown.

6. An adapter was designed for quickly mounting the instrument on a light, collapsible tripod. Height of the instrument can be adjusted swiftly, and one-handle control serves for both lateral and vertical alignment. A worm-gear assembly was added for micrometer adjustment of side-tilt, and the lock-knob of the tripod platform was spring-loaded to permit small adjustments of vertical alignment.

Weight of the instrument is 3¾ pounds (1.73 kg.) without tripod, and 8½ pounds (3.88 kg.) with Safelock Model FL tripod and Bruce worm-gear assembly.[6] The instrument may be folded against the tripod without disassembly.

[6] The tripod is made by Safelock, Hialeah, Fla., with tripod platform worm-gear assembly by the Bruce Co., Springfield, Mo.

OPERATING THE MODIFIED TELETOP

Distance measurement.—The counter-rotating prism assembly is rotated into true coincidence mode and swung into the line of sight, with the prisms preset against the distance stop. With the collimating sight, the instrument is aimed at the tree. The telescopic image is adjusted so that the vertical reference line (etched on the fixed pentaprism) is near the line of coincidence, and the halving-line (separating the split images) is square across the tree section to be measured. The movable prism is shifted for true coincidence of the images, and the distance is then read as feet and tenths on the measuring scale.

Diameter measurement.—If the tree diameter is less than the length of the measuring scale, the prism assembly is swung out of place, the images are adjusted for false coincidence, and diameter is read on the scale in inches and tenths.

If tree diameter is greater than the length of the scale, the true-coincidence setting for distance measurement may also suffice as the first reading of diameter, provided that the scale setting in inches is half or more of the tree diameter. In this case, the prism assembly is rotated 180° (false coincidence mode), and a second reading in inches is obtained with the images adjusted for false coincidence. The two scale readings are added.

If the scale length needed for true coincidence setting in measuring distance is less than half that required for the diameter to be measured, the rail scale will be too short to permit false coincidence to be achieved. The movable prism is then shifted out on the rail for at least one-half of the estimated diameter, and the images are realigned into true coincidence by adjusting the counter-rotation of the prisms. With no change in this prism setting, the prism assembly is rotated 180°, the images are aligned for false coincidence, and the second reading for diameter is made.

Height measurement.—The clinometer is read in degrees and tenths. Since the scale is graduated in (degrees + 100), a reading of 105.2° is an elevation of (105.2 — 100) = 5.2,

and a reading of 94.8° is a depression of (94.8 — 100) = —5.2. For a slant distance of 80 feet, corresponding height above or below horizontal is (80 × sine ± 5.2°) = ± 7.2 feet.

REFINEMENTS FOR EXTENDING INSTRUMENT CAPACITY

Either of two refinements (not present on the prototype illustrated in figure 5) will increase both diameter and distance capacity without increasing rail length. Method 1, as described below, gives good approximations and has the advantage of being functional at practically any instrument location. Method 2, suggested by David Bruce of the Pacific Northwest Forest and Range Experiment Station, USDA Forest Service, is more precise but may require changes in instrument location.

Method 1.—The movable prism is shifted to the end of the measuring scale, and the counter-rotating prisms are adjusted for true coincidence. When the prism assembly is rotated 180°, the left side of the movable image will fail, by some interval "A" shown in figure 6, to achieve false coincidence. This deficiency can be measured on the rail scale by pulling the movable pentaprism back for an image distance corresponding to the deficiency. Diameter is then twice scale length, plus the deficiency, measured back from the right end of the scale.

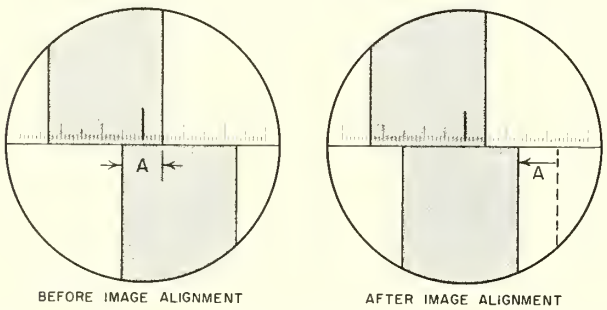

Figure 6.—*Desirable image-plane reference scale for measuring rail-length deficiency. The interval A is a measure of rail-length deficiency for diameter.*

Error in measuring this deficiency can be reduced if a reference scale is etched on the image plane (fig. 6). Reading can be facilitated by graduating the rail scale to read from right to left of zero, as well as from left to right.

Method 2.—This method requires fitting the prism assembly with a series of mechanical stops, each halving the preceding ratio, e. g., 1:240, 1:120, 1:60, 1:30, and 1:15. True coincidence is first obtained with the counter-rotating prisms stopped in any of the first four positions. The prisms are then advanced one stop, e. g., from 1:120 to 1:60, and rotated 180°, after which the images are readjusted for false coincidence. Tree diameter is then equivalent to twice the scale reading with images adjusted for true coincidence, plus the scale reading with images readjusted for false coincidence.

With these methods, the modified Teletop can accommodate a diameter of 54 inches at any working distance beyond 23 feet, provided that the scale-length is 18 inches and the counter-rotating prisms are set for a ratio of 1:15. Smaller diameters may be measured at shorter distances.

An accessory plug-in rail extension 10 inches long is feasible, and can increase caliper diameters to 28 inches and total diameter capacity to 84 inches at distances beyond 35 feet, distance capacity to 280 feet from 180 feet, and height capacity to ± 242 feet from ± 156 feet. With the prisms stopped for a ratio of 1:240, distance and height capacities are doubled.

MEASUREMENT ACCURACY AND PRECISION

Measurements of diameter at breast height were made with the modified Teletop on 12 hardwood trees that ranged from 10 to 27 inches in diameter and were 41 to 105 feet distant from the instrument. The optical estimates were made by sighting across two finishing nails extending from the sides of the trees. Measurement checks were made by placing the arms of a caliper on these nails and sighting back at the instrument, in an effort to duplicate the lines of sight. The Teletop measurements were 0.4 percent low, and the coefficient of variation of measured diameter/estimated diameter was ± 0.5 percent.

Error in estimates of slant distance to these trees averaged +0.4 percent, and CV of measured distance/estimated distance was ±1.5 percent. Most of the variation in distance was

caused by gear-play in the counter-rotating prism assembly.

Height estimates were checked by nine sightings, from —8 to 54°, on a 33-foot measuring pole graduated to 0.1 foot. The coefficient of variation of measured tangent/estimated tangent was ±1.4 percent, and that for measured height/estimated height was ± 0.3 percent.

MODIFIED TELETOP COMPARED WITH BARR AND STROUD DENDROMETER

In accuracy and precision the modified Teletop is comparable to the Barr and Stroud dendrometer, currently the only field-going, magnifying dendrometer with coincident split images. The Barr and Stroud instrument is more compact, provides a somewhat brighter and correctly oriented erect image, includes a more precise clinometer, requires less practice for effective use, is less likely to be thrown out of adjustment, and has a measurement range adequate for any tree size. On the other hand, anticipated cost of the modified Teletop is much smaller, its range is adequate for all but the largest trees, and measuring speed by an experienced operator is about the same. It can be operated at closer distances (necessitating less line-clearing), its measuring scale reads direct for diameter and slant distance (Barr and Stroud readings are not direct), and its weight with tripod is substantially less.

SIMPLER MODIFICATIONS FOR OTHER APPLICATIONS

An unaltered optical system from a Teletop, fitted with a hypsometer and tripod adapter, as shown by figure 7, is effective for measuring stem diameters and heights of comparatively small trees, and heights to and diameters of specific overhead branches.

The telescope is easily repositioned for horizontal viewing, and the instrument can readily be adapted for hand-held viewing (fig. 8). Images are inverted, but this arrangement facilitates use in dendrometry required for applying volume tables, such as determining diameters to fixed or variable tops, measuring heights above stump without measuring distance from the tree, and checking tree form class. Good approximations of Girard form class can be made by dividing top diameter of the first 16-foot log, outside bark, by DBHOB + double bark thickness at BH.[7]

The purchaser of the unaltered Teletop optical system can probably make these two simple adaptations himself.

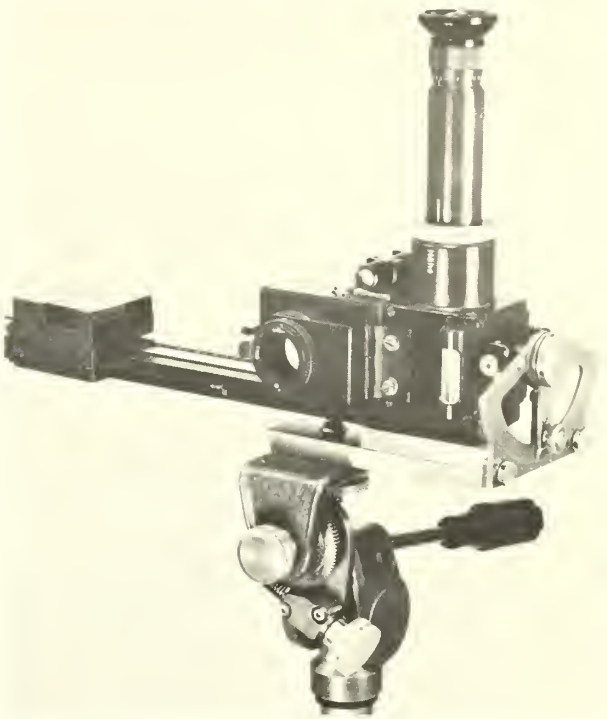

Figure 7.—*Arc and bubble from an Abney hand level added to optical system of a Teletop.*

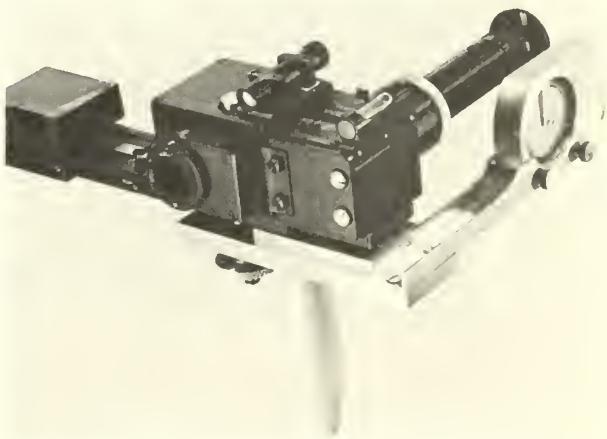

Figure 8.—*Adaptation of the Teletop optical system for hand-held viewing. Here the instrument is linked with a Suunto clinometer graduated in degrees.*

[7] Judson, G. M. Inexpensive and accurate form-class estimates. USDA Forest Serv. Res. Pap. SO-11, 6 pp. South. Forest Exp. Sta., New Orleans, La. 1964.

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TIMBER DAMAGED By HURRICANE CAMILLE IN MISSISSIPPI

Dwane D. Van Hooser and Arnold Hedlund

SOUTHERN FOREST EXPERIMENT STATION

Damage totaled about 290 million cubic feet of growing stock and 1.2 billion board feet of sawtimber in 15 counties in southern Mississippi.

A forest survey of 15 counties in southern Mississippi was carried out to estimate the volume of timber damaged by Hurricane Camille, which struck the Gulf Coast on August 17. The results of that work, which was done by the Southern Station's Forest Survey Unit, are reported here.

The area of major damage was delineated through aerial reconnaissance by the Division of Forest Pest Control of the USDA Forest Service. Fifteen counties in southern Mississippi sustained sufficient damage to justify on-the-ground measurements at sample locations. In this area, sample locations were spaced at approximately 4-mile intervals. At each sample location, paired points 117.8 feet apart were established, and from each point information was gathered on all trees within the range of a prism with a basal area factor of 10. A total of 682 point samples were taken between September 3 and 17. Some of the field work was done by personnel from the Yazoo-Little Tallahatchie Flood Prevention Project, USDA Forest Service. The data were summarized with the computer facilities of the National Aeronautics and Space Administration in New Orleans.

The results indicate that about 290 million cubic feet of growing stock were damaged by the storm. Included in this estimate are some 1.2 billion board feet of sawtimber. The loss in growing stock amounts to approximately one-tenth of the timber inventory in the 15-county area before the storm. The area where damage was most severe is shown in figure 1. Hancock County was hardest hit. One-third of its standing inventory was damaged. Proportions of 1967 county inventories damaged by Camille, by species group, were:

County	Total	Softwood	Hardwood
	– – – – *Percent* – – – –		
Covington	6.5	11.5	2.5
Forrest	9.7	10.0	8.0
George	.9	1.4	(1)
Hancock	37.2	35.6	41.9
Harrison	21.5	22.4	17.7
Jackson	8.1	7.5	8.9
Jefferson Davis	9.8	10.4	8.8
Jones	(1)	(1)	(1)
Lamar	29.3	27.3	34.6
Lawrence	.6	(1)	1.6
Marion	5.1	7.1	2.8
Pearl River	29.2	34.0	21.0
Perry	1.0	1.4	(1)
Simpson	(1)	(1)	(1)
Stone	8.4	10.3	1.9
All counties	10.5	11.6	8.3

[1] Negligible.

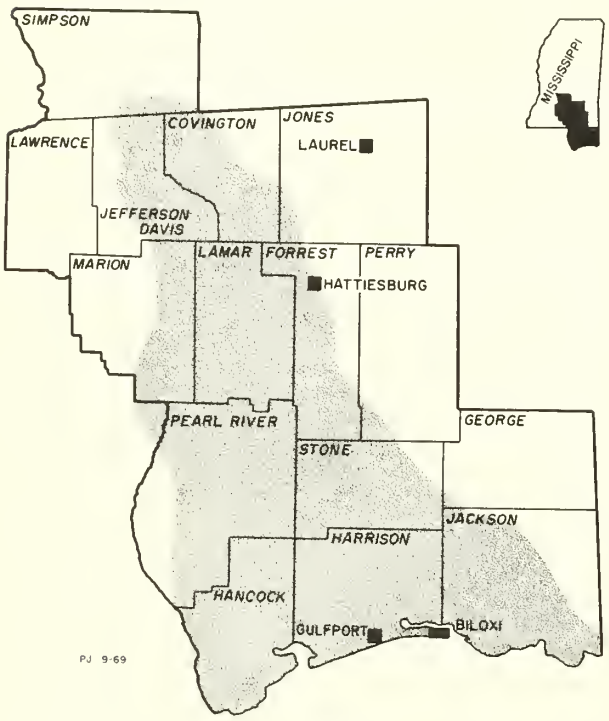

Figure 1.—*Area of major timber damage from Hurricane Camille.*

Nearly three-fourths of the damaged volume is pine, which is the major raw material for most forest products industries in the area. The southern pines did not appear to be more vulnerable than hardwoods, however. The high pine losses were attributable mainly to the high proportion of these species in the area's forests, and particularly in managed stands.

Loss in pines was largely due to breakage in the lower portion of the stems. Blowdown was the major form of hardwood damage.

Field estimates on each plot indicate that about 95 percent of the volume is physically salvable for pulpwood. Stem breakage has destroyed some potential saw logs, but 85 percent of the sawtimber volume is also probably salvable. In sawtimber-sized trees, there is about 20 million cubic feet of material suitable for pulpwood in addition to the 85 percent that can still be made into saw logs.

To fully comprehend the damage inflicted by Hurricane Camille, the losses must be compared with annual growth and cut in the 15 counties. If growth were to continue at the same rate as before the storm *(2)*, it would take an average of 1.7 years to replace the lost volume. In the hardest hit counties, the time is considerably longer. If growth could proceed as in the past—a highly unlikely occurrence—it would take nearly 6 years to replace the losses in Hancock County, 5 years in Lamar and Pearl River Counties, and 3 years in Harrison County.

In one night the industrial base was reduced by more than three times the annual harvest in the 15 counties in 1966 *(3)*. In Hancock County storm damage amounted to 14 times the annual harvest; in Harrison County it was 12, in Lamar seven, and in Pearl River eight times the annual harvest.

The damaged growing stock is equivalent to 4 million standard cords. This volume exceeds the round pulpwood production in Mississippi in 1968 *(1)* by 800,000 cords.

The sampling errors (on a probability of two chances out of three) associated with the estimated totals are plus or minus 8.5 percent for damaged growing stock volume and 9.7 percent for sawtimber volume. As the totals are broken down by various subdivisions, the possibility of error increases. It is greatest for the smallest items.

All data in this report are directly comparable to the statistics contained in a recent report on forests in Mississippi counties *(2)*.

LITERATURE CITED

1. Beltz, R. C.
   1969. Southern pulpwood production, 1968. USDA Forest Serv. Resource Bull. SO-18, 21 pp. South. Forest Exp. Sta., New Orleans, La.
2. Hedlund, A., and Earles, J. M.
   1969. Forest statistics for Mississippi counties. USDA Forest Serv. Resource Bull. SO-15, 24 pp. South. Forest Exp. Sta., New Orleans, La.
3. Van Hooser, D. D.
   1968. Mississippi forest industry. USDA Forest Serv. Resource Bull. SO-12, 25 pp. South. Forest Exp. Sta., New Orleans, La.

Table 1.—*Volume of storm-damaged growing stock on commercial forest land, by species group and county, Mississippi, 1969*

County	All species	Softwood			Hardwood			
		Total	Pine	Other	Total	Gum	Oak	Other
	Million cubic feet							
Covington	8.9	7.0	7.0	(1)	1.9	(1)	1.2	0.7
Forrest	13.6	12.0	12.0	...	1.6	(1)	1.6	(1)
George	1.4	1.4	1.4	(1)	(1)	(1)	(1)	(1)
Hancock	51.3	36.3	33.7	2.6	15.0	3.0	6.0	6.0
Harrison	53.0	45.3	45.3	(1)	7.7	(1)	3.8	3.9
Jackson	25.1	12.9	12.9	(1)	12.2	(1)	(1)	12.2
Jefferson Davis	9.9	6.7	6.7	...	3.2	(1)	2.1	1.1
Jones	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Lamar	39.2	26.4	26.4	..	12.8	(1)	4.4	8.4
Lawrence	.9	(1)	(1)	(1)	.9	(1)	(1)	.9
Marion	7.4	5.5	5.5	...	1.9	(1)	(1)	1.9
Pearl River	60.8	44.8	44.8	(1)	16.0	2.2	6.9	6.9
Perry	2.6	2.6	2.6	(1)	(1)	(1)	(1)	(1)
Simpson	..	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Stone	15.6	14.8	14.8	(1)	.8	(1)	.8	(1)
All counties	289.7	215.7	213.1	2.6	74.0	5.2	26.8	42.0

[1] Negligible.

Table 2.—*Volume of storm-damaged sawtimber on commercial forest land, by species group and county, Mississippi, 1969*

County	All species	Softwood			Hardwood			
		Total	Pine	Other	Total	Gum	Oak	Other
	Million board feet [1]							
Covington	38.6	27.8	27.8	(2)	10.8	(2)	6.9	3.9
Forrest	61.3	52.6	52.6	..	8.7	(2)	8.7	(2)
George	6.6	6.6	6.6	(2)	(2)	(2)	(2)	(2)
Hancock	205.6	146.9	132.7	14.2	58.7	13.0	25.9	19.8
Harrison	200.0	172.1	172.1	..	27.9	(2)	16.2	11.7
Jackson	110.3	52.7	52.7	(2)	57.6	(2)	(2)	57.6
Jefferson Davis	20.6	13.8	13.8	...	6.8	(2)	3.9	2.9
Jones	(2)	(2)	(2)	..	(2)	(2)	(2)	(2)
Lamar	149.6	114.0	114.0	...	35.6	(2)	13.5	22.1
Lawrence	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Marion	36.9	27.1	27.1	...	9.8	(2)	(2)	9.8
Pearl River	256.3	195.0	195.0	(2)	61.3	11.3	29.4	20.6
Perry	15.8	15.8	15.8	(2)	(2)	(2)	(2)	(2)
Simpson	(2)	(2)	(2)	...	(2)	(2)	(2)	(2)
Stone	74.8	74.8	74.8	(2)	(2)	(2)	(2)	(2)
All counties	1,176.4	899.2	885.0	14.2	277.2	24.3	104.5	148.4

[1] International ¼-inch rule.
[2] Negligible.

Table 3.—*Volume of storm-damaged sawtimber on commercial forest land, by species group, diameter class, and county, Mississippi, 1969*

County	All species	Softwood			Hardwood		
		Total	9.0-14.9 inches	15.0 inches and up	Total	11.0-14.9 inches	15.0 inches and up
	Million board feet [1]						
Covington	38.6	27.8	22.3	5.5	10.8	(2)	10.8
Forrest	61.3	52.6	36.1	16.5	8.7	(2)	8.7
George	6.6	6.6	6.6	(2)	(2)	(2)	(2)
Hancock	205.6	146.9	108.8	38.1	58.7	38.3	20.4
Harrison	200.0	172.1	164.8	7.3	27.9	18.9	9.0
Jackson	110.3	52.7	52.7	(2)	57.6	19.3	38.3
Jefferson Davis	20.6	13.8	13.8	(2)	6.8	2.9	3.9
Jones	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Lamar	149.6	114.0	60.0	54.0	35.6	18.5	17.1
Lawrence	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Marion	36.9	27.1	27.1	(2)	9.8	9.8	(2)
Pearl River	256.3	195.0	133.6	61.4	61.3	39.1	22.2
Perry	15.8	15.8	(2)	15.8	(2)	(2)	(2)
Simpson	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Stone	74.8	74.8	55.9	18.9	(2)	(2)	(2)
All counties	1,176.4	899.2	681.7	217.5	277.2	146.8	130.4

[1] International ¼-inch rule.
[2] Negligible.

Table 4.—*Volume of storm-damaged growing stock on commercial forest land, by damage class, Mississippi, 1969*

Damage class	Pine	Other softwoods	Gum	Oak	Other hardwoods
	Million cubic feet				
Broken stem:					
Poletimber	25.0	0.5	0.5	1.9	4.3
Sawtimber—above saw-log section	17.3	2.1	1.3	3.0	8.6
Sawtimber—within saw-log section	78.7	(1)	1.9	2.4	4.6
Total	121.0	2.6	3.7	7.3	17.5
Blown-down	74.0	(1)	1.5	12.7	23.4
Leaning—root damage	13.3	(1)	(1)	6.8	1.1
Salvaged [2]	4.8	...	...	..	...
All classes	213.1	2.6	5.2	26.8	42.0

[1] Negligible.
[2] Includes only volume salvaged prior to field investigation.

Table 5.—*Volume on commercial forest land of salvable storm-damaged growing stock not meeting saw log specifications, by softwoods and hardwoods, and county, Mississippi, 1969*

County	Total	Softwoods	Hardwoods
	Million cubic feet		
Covington	2.2	1.9	0.3
Forrest	2.3	2.3	(1)
George	.5	.5	(1)
Hancock	19.5	14.9	4.6
Harrison	13.9	11.9	2.0
Jackson	3.9	2.3	1.6
Jefferson Davis	5.3	3.6	1.7
Jones	(1)	(1)	(1)
Lamar	13.1	7.0	6.1
Lawrence	.8	(1)	.8
Marion	.6	.6	(1)
Pearl River	17.0	11.9	5.1
Perry	(1)	(1)	(1)
Simpson	(1)	(1)	(1)
Stone	2.0	1.2	.8
All counties	81.1	58.1	23.0

[1] Negligible.

SOUTHERN FOREST EXPERIMENT STATION

1969

U.S. FOREST SERVICE RESEARCH NOTE

SO-97

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FOREST FIRE OCCURRENCE IN THE SOUTH, 1956-1965[1]

M. L. Doolittle
SOUTHERN FOREST EXPERIMENT STATION

Public reaction to local programs for preventing man-caused forest fires cannot readily be evaluated without statistics on fire occurrence in individual protection districts. This note provides such information for State-protected land in the southern U. S., including Kentucky, from 1956 through 1965.

The basic data were obtained from the State Foresters, each of whom was asked to provide annual totals of fire occurrence—i. e., number of fires—for each county under organized protection during part or all of the decade. In Arkansas and Oklahoma, data by county were not available for all years, and hence the information for these States is in terms of fire-protection districts, most of which include all or parts of two or more counties. The State Foresters provided data for 888 counties or other units, but 84 were excluded from analysis because they had been under protection for less than 5 years.

Ninety-eight percent of the forest fires occurring in the South are man-caused; the rest are chiefly from lightning strikes.[2] No effort was made to classify fires according to reported cause, for variations in reporting and classifying procedures limit comparisons of data from different States. Neither did it seem feasible to include information on weather, timber type, fuel, or other factors that influence the start and spread of fires.

Fire occurrence rate for a county or district was computed as the number of fires per million acres protected:

$$\text{Rate} = \frac{\text{Number of fires}}{\text{Acres protected}} \times 1{,}000{,}000$$

Acres protected was defined as the sum of acreages protected each year.

[1] The data for this report were compiled and analyzed with the assistance of the Social Science Research Center, Mississippi State University. F. Bruce Johnson, graduate assistant, was especially helpful.

[2] USDA Forest Service. 1966 forest fire statistics. Div. Cooperative Forest Fire Control, State and Priv. Forest., 52 pp. 1967.

The 804 protection units were classified into five occurrence-rate categories:

Category	Range of occurrence rates	Protection units in category
		No.
Very low	0-132	168
Low	133-206	161
Moderate	207-282	153
High	283-407	160
Very high	408+	162
		804

Table 1 summarizes the distribution of protection units in each State by category. Geographical distribution is indicated in figure 1 pages 8 and 9). Tables 2 to 14 show, for counties or other protection units within States, the number of fires, number of protected acres, and fire rates over the 10-year span; rank of protection units within States is also indicated (protection units for which data are incomplete or unavailable are omitted from the tables). Tables of occurrence by year may be obtained from USDA Forest Service, P. O. Box FX, State College, Mississippi 39762.

Table 1.--*Number and percent of protection units in each occurrence rate category by State, 1956-65*[1]

States	Very low		Low		Moderate		High		Very high		Total
	No.	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*
Alabama	11	16	10	15	17	25	10	15	19	28	67
Arkansas	5	22	9	39	4	17	5	22	0	0	23
Florida	7	13	8	15	10	19	16	30	12	23	53
Georgia	6	5	15	12	25	20	37	30	42	34	125
Kentucky	6	9	16	23	22	32	18	26	7	10	69
Louisiana	4	10	12	29	6	15	6	15	13	32	41
Mississippi	3	4	14	19	11	15	12	16	34	46	74
North Carolina	37	40	28	30	9	10	13	14	5	5	92
Oklahoma	1	17	2	33	2	33	1	17	0	0	6
South Carolina	2	4	13	28	7	15	10	22	14	30	46
Tennessee	6	8	10	14	22	30	26	35	10	14	74
Texas	16	41	6	15	10	26	3	8	4	10	39
Virginia	64	67	18	19	8	8	3	3	2	2	95
Region	168	21	161	20	153	19	160	20	162	20	804

[1]Because of rounding, percentage totals for States do not always equal 100.

Table 2.--*Alabama*

County	Fires	Protected area	Av. fire rate	Rank in State	County	Fires	Protected area	Av. fire rate	Rank in State
	No.	*M acres*				*No.*	*M acres*		
Autauga	654	2,430	269	37	Houston	559	1,256	445	53
Baldwin	4,536	7,745	585	58	Jackson	652	3,952	164	14
Barbour	655	3,442	190	16	Jefferson	4,796	5,054	948	67
Bibb	669	2,678	249	30	Lamar	577	2,810	205	20
Blount	1,022	2,442	418	51	Lauderdale	431	1,397	308	44
Bullock	509	2,103	242	27	Lawrence	212	1,054	201	18
Butler	864	3,511	246	29	Lee	714	2,430	293	41
Calhoun	918	2,117	433	52	Limestone	89	850	104	6
Chambers	370	2,472	149	12	Lowndes	229	2,307	99	5
Cherokee	820	2,449	334	47	Macon	825	2,009	410	49
Chilton	1,480	2,972	497	60	Madison	315	1,536	205	21
Choctaw	789	4,862	162	13	Marengo	460	3,694	124	9
Clarke	426	6,834	62	1	Marion	988	3,242	304	42
Clay	532	2,372	224	25	Marshall	861	1,408	611	64
Cleburne	1,068	2,151	496	59	Mobile	3,732	5,933	629	65
Coffee	604	2,403	251	31	Monroe	610	5,073	120	8
Colbert	462	2,080	222	23	Montgomery	447	1,844	242	28
Conecuh	865	3,770	229	26	Morgan	533	1,276	417	50
Coosa	884	3,349	263	35	Perry	296	2,656	111	7
Covington	1,304	3,987	327	46	Pickens	904	4,058	222	24
Crenshaw	407	2,442	166	15	Pike	679	2,094	324	45
Cullman	790	2,574	306	43	Randolph	704	2,471	272	39
Dale	413	1,619	255	32	Russell	1,036	2,145	482	57
Dallas	393	3,112	126	11	St. Clair	1,714	3,089	554	63
De Kalb	607	2,322	261	33	Shelby	1,795	3,833	468	54
Elmore	691	2,595	266	36	Sumter	279	3,554	78	3
Escambia	2,327	4,658	499	61	Talladega	1,411	2,585	545	62
Etowah	1,252	2,164	578	56	Tallapoosa	972	3,330	291	40
Fayette	591	3,033	194	17	Tuscaloosa	1,916	6,909	277	38
Franklin	844	2,368	356	48	Walker	2,340	3,617	646	66
Geneva	760	1,608	472	55	Washington	1,212	5,956	203	19
Greene	319	2,540	125	10	Wilcox	270	3,915	68	2
Hale	193	2,094	92	4	Winston	495	2,273	217	22
Henry	526	2,018	261	34					

Table 3.--*Arkansas*

District	Fires	Protected area	Av. fire rate	Rank in State	District	Fires	Protected area	Av. fire rate	Rank in State
	No.	*M acres*				*No.*	*M acres*		
1 Crossett	2,213	6,219	355	22	13 Harrison	1,171	6,668	175	7
2 Dierks	1,520	7,581	200	13	14 Hardy	2,058	5,510	373	23
3 Fordyce	1,969	7,488	262	17	15 Eureka Springs	1,210	6,230	194	12
4 Warren	1,268	6,656	190	11	16 Salem	1,431	7,703	185	10
5 Malvern	1,998	7,137	279	18	17 Perryville	1,369	6,645	206	14
6 Delight	1,251	6,886	181	9	18 Heber Springs	1,116	6,876	162	6
7 Sheridan	2,079	6,602	314	20	19 Mountain View	1,544	8,750	176	8
8 El Dorado	2,399	7,311	328	21	20 Jonesboro	153	9,261	16	3
9 Stamps	2,361	8,287	284	19	21 Forrest City	74	6,670	11	2
10 Ashdown	1,496	7,170	208	15	22 Stuttgart	78	10,513	7	1
11 Ozark	853	10,826	78	4	23 Batesville	634	5,530	114	5
12 Fayetteville	1,224	5,364	228	16					

Table 4.--*Florida*

County	Fires	Protected area	Av. fire rate	Rank in State	County	Fires	Protected area	Av. fire rate	Rank in State
	No.	*M acres*				*No.*	*M acres*		
Alachua	1,309	3,770	347	36	Jefferson	441	2,850	155	8
Baker	847	2,780	305	28	Lake	1,306	4,010	326	31
Bay	1,190	4,470	266	23	Lee	2,078	4,772	435	44
Bradford[1]	811	1,197	677	50	Leon	742	2,230	333	32
Calhoun	595	3,250	183	9	Levy	1,119	5,340	209	18
Charlotte[1]	1,114	2,934	379	38	Liberty	291	2,310	126	7
Clay	1,315	3,010	437	45	Madison	570	3,030	188	11
Collier	904	2,625	344	35	Manatee	669	3,150	212	19
Columbia	902	2,940	307	30	Marion	1,577	5,870	268	24
Dade	7	995	7	1	Nassau	1,017	3,840	265	22
Dixie	1,398	4,764	293	27	Okaloosa	919	3,310	277	25
Duval	3,747	4,600	814	51	Orange	2,102	4,280	491	46
Escambia	2,414	3,590	672	49	Pinellas	1,876	1,730	1,084	53
Flagler	345	2,742	126	6	Putnam[1]	1,092	3,735	292	26
Franklin	281	3,090	91	3	St. Johns	1,302	3,330	391	41
Gadsden	874	2,280	383	40	Santa Rosa	3,257	5,450	597	48
Gilchrist[2]	163	852	191	13	Sarasota	845	2,340	361	37
Glades[3]	195	2,200	88	2	Seminole	1,180	1,330	887	52
Gulf	415	3,370	123	5	Sumter[2]	376	1,230	305	29
Hamilton	503	2,670	188	10	Suwannee[3]	445	2,016	221	20
Hendry	286	1,400	204	15	Taylor	1,243	6,420	193	14
Hernando[1]	949	2,763	343	34	Union	253	1,220	207	16
Highlands[1]	313	2,677	117	4	Volusia	2,745	6,539	420	43
Hillsborough	3,282	5,855	560	47	Wakulla	408	1,070	381	39
Holmes	771	2,250	342	33	Walton	1,369	5,450	251	21
Indian River	614	1,460	420	42	Washington	661	3,180	208	17
Jackson	730	3,840	190	12					

[1]Not protected prior to 1957.
[2]Not protected prior to 1960
[3]Not protected prior to 1958

Table 5.--*Georgia*

County or District	Fires	Protected area	Av. fire rate	Rank in State
	No.	*M acres*		
Appling	754	2,502	301	55
Bacon	509	1,296	393	80
Baldwin, Hancock[1]	836	3,480	240	38
Bartow	834	1,862	448	89
Ben Hill	383	1,066	359	70
Berrien	619	2,098	295	51
Bibb[2]	693	1,166	594	110
Bleckley	248	668	371	75
Brantley	449	2,527	178	16
Brooks	371	1,770	210	23
Bryan	537	1,492	360	71
Bulloch	929	2,440	381	78
Burke	1,370	2,736	501	97
Butts, Henry[1]	865	1,768	489	95
Calhoun[3]	402	1,015	396	81
Camden	537	3,108	173	13
Candler	513	968	530	103
Carroll[4]	1,246	1,870	666	115
Catoosa	313	596	525	102
Charlton	522	3,339	156	10
Chatham	722	1,204	600	111
Chattahoochee	184	706	261	41
Chattooga	563	1,268	444	88
Cherokee	874	1,888	463	92
Clarke, Oconee[1]	335	947	354	69
Clay[3]	118	675	175	15
Clayton, Fayette[5]	1,014	938	1,081	123
Cobb	1,236	1,194	1,035	122
Coffee, Atkinson[1]	1,092	3,475	314	58
Colquitt	825	1,658	498	96
Columbia	313	1,360	230	31
Cook	369	872	423	86
Coweta	701	1,874	374	76
Crawford[6]	430	1,911	225	29
Crisp, Dooly[1]	716	1,735	413	85
Dade	585	843	694	118
Dawson	206	1,050	196	19
Decatur	791	2,404	329	60
De Kalb	966	892	1,082	124
Dodge	717	1,938	370	74
Dougherty	251	940	267	44
Douglas[4]	530	696	761	120
Early	344	1,572	219	26
Echols	224	2,554	88	2
Effingham	717	2,562	280	45
Elbert, Madison[1]	546	2,362	231	33
Emanuel	1,389	2,922	475	93
Evans	241	624	386	79
Fannin	395	1,146	345	67
Floyd	1,367	2,038	671	116
Forsyth[7]	536	1,192	450	90
Franklin, Hart[1]	337	1,456	231	34
Fulton	1,059	1,498	707	119
Gilmer[8]	292	2,114	138	8
Glynn	1,011	1,720	588	109
Gordon	396	1,144	346	68
Grady	369	1,720	214	25
Greene, Taliaferro[9]	280	2,709	103	5
Gwinnett	921	1,580	583	108
Habersham, White[10]	329	1,960	168	11
Hall, Banks[1]	1,010	2,734	369	73
Haralson[11]	1,094	1,628	672	117
Harris	689	2,454	281	46
Heard	391	1,511	259	40
Irwin	312	1,358	230	32
Jackson, Barrow[1]	481	1,614	298	53
Jasper, Jones[1]	721	3,277	220	27
Jefferson[12]	519	1,815	286	47
Jenkins	727	1,196	608	112
Lamar[17]	262	414	633	113
Laurens	768	2,892	266	43
Lee	410	966	425	87
Liberty	1,152	1,402	822	121
Lincoln	128	756	169	12
Long	611	2,128	287	48
Lowndes	833	2,463	338	63
Lumpkin	223	1,137	196	20
McDuffie, Warren[1]	390	2,136	182	17
Macon[13]	340	1,488	228	30
Marion, Schley[14]	482	2,377	203	21
Meriwether	592	2,370	250	39
Miller	345	852	405	83
Mitchell[15]	741	1,442	514	100
Monroe[2]	402	1,896	212	24
Montgomery, Wheeler[16]	675	2,153	314	59
Morgan, Walton[1]	552	2,354	234	37
Murray	350	1,341	261	42
Muscogee	373	310	1,203	125
Newton, Rockdale[1]	971	1,501	647	114
Oglethorpe	162	1,850	88	3
Paulding	776	1,532	506	98
Pickens	628	1,158	542	105
Pierce	525	1,540	341	66
Pike, Spalding[17]	982	1,929	509	99
Polk[11]	508	954	532	104
Pulaski, Houston[18]	517	1,697	305	57
Putnam	205	1,539	133	7
Rabun	92	752	122	6
Richmond	473	902	524	101
Screven	815	2,412	338	64

Table 5.--*Georgia (continued)*

County or District	Fires	Protected area	Av. fire rate	Rank in State
	No.	*M acres*		
Seminole	286	840	340	65
Stephens[10]	128	444	288	49
Stewart, Webster[19]	277	2,772	100	4
Sumter	684	1,488	460	91
Talbot	371	2,148	173	14
Tattnall	512	2,200	233	36
Taylor[6]	306	1,644	186	18
Telfair, Jeff Davis[20]	945	2,815	336	62
Terrell, Randolph[21]	416	1,990	209	22
Thomas	609	2,016	302	56
Tift, Turner[1]	683	1,716	398	54
Toombs	801	1,444	555	107
Treutlen[16]	247	656	376	77
Troup	602	2,074	290	50
Twiggs[22]	704	2,126	331	61
Upson[17]	523	1,449	361	72
Walker	776	1,888	411	84
Ware	1,013	3,435	295	52
Washington[23]	720	3,211	224	28
Wayne	828	3,586	231	35
Whitfield	521	945	551	106
Wilcox	690	1,414	488	94
Wilkes	147	2,186	67	1
Wilkinson[22]	325	2,178	149	9
Worth	755	1,872	403	82

[1]Combined throughout the decade 1956-1965.
[2]Bibb and Monroe combined in 1965.
[3]Calhoun and Clay combined in 1965.
[4]Carroll and Douglas combined in 1964.
[5]Fayette county added in 1960.
[6]Peach county added in 1962; Taylor county added in 1965.
[7]Northern part of Fulton county added in 1962.
[8]Not reported in 1956.
[9]Greene and Taliaferro combined in 1957.
[10]Combined throughout the period; Stephens county added in 1964.
[11]Haralson and Polk combined in 1964.
[12]Jefferson and Glascock combined in 1964.
[13]Schley county added in 1965.
[14]Combined through 1964.
[15]Baker county added in 1965.
[16]Wheeler county was reported separately in 1956 and 1957, was not reported at all in 1958, 1959, or 1960, and then was combined with Montgomery county in 1961. Here, the separate 1956 and 1957 data have been combined with Montgomery for these years, also. Treutlen county was added in 1964.
[17]Combined throughout the period. Lamar county added in 1962; Upson county added in 1965.
[18]Houston county added in 1959.
[19]Webster county added in 1960.
[20]Jeff Davis county added in 1961.
[21]Randolph county added in 1959.
[22]Twiggs and Wilkinson combined in 1965.
[23]Johnson county added in 1963.

Table 6.--*Kentucky*

County	Fires	Protected area	Av. fire rate	Rank in State	County	Fires	Protected area	Av. fire rate	Rank in State
	No.	*M acres*				*No.*	*M acres*		
Adair[1]	135	741	182	18	Leslie	959	2,171	441	64
Bath[1]	51	310	165	13	Letcher	678	1,806	376	59
Bell	616	1,896	324	51	Lewis	324	2,286	141	9
Boyd	223	568	392	47	Livingston	194	748	259	40
Breathitt	850	2,558	333	53	Logan[3]	55	545	101	4
Breckinridge[2]	210	1,239	169	15	Lyon	172	715	240	31
Bullitt	191	805	237	29	McCracken[3]	49	190	258	37
Butler[3]	101	675	150	11	McCreary[3]	109	435	251	35
Caldwell	96	440	219	26	McLean[3]	62	225	276	43
Calloway	197	761	259	38	Magoffin	595	1,494	398	61
Carter	741	1,720	430	63	Marshall	100	425	235	28
Casey[3]	228	765	298	49	Martin	800	1,280	625	67
Christian	273	1,315	208	23	Meade	185	757	244	33
Clay	891	2,229	399	62	Menifee[4]	71	707	100	3
Clinton	139	696	200	20	Metcalfe[3]	71	440	161	12
Crittenden	226	888	254	36	Monroe[3]	117	490	239	30
Cumberland[4]	261	1,008	259	39	Morgan	490	1,564	313	50
Elliott	300	1,117	269	42	Muhlenberg	456	1,374	331	52
Estill	251	1,178	213	24	Nelson	76	1,099	69	2
Fleming	74	641	115	6	Ohio[3]	162	975	166	14
Floyd	1,271	1,840	690	68	Owsley	338	896	377	60
Graves[3]	116	400	290	46	Perry	1,335	1,791	746	69
Greenup	529	1,546	342	56	Pike	1,173	4,264	275	44
Hancock[3]	60	280	214	25	Powell[3]	76	340	224	27
Hardin	380	1,115	341	55	Pulaski[3]	171	930	184	19
Harlan[3]	773	2,642	292	48	Rockcastle[2]	240	997	241	32
Hart[3]	140	560	250	34	Rowan	172	974	177	17
Hopkins	569	1,661	343	57	Russell[3]	107	315	340	54
Jackson[3]	73	545	134	7	Taylor[1]	93	461	202	21
Johnson	677	1,236	548	66	Todd[3]	13	305	43	1
Knott	722	1,925	375	58	Trigg	177	1,264	140	8
Knox	751	1,665	451	65	Wayne	193	1,718	112	5
Laurel	196	1,383	142	10	Whitley	330	1,878	176	16
Lawrence	571	1,982	288	48	Wolfe	175	862	203	22
Lee	265	995	266	41					

[1]Not protected prior to 1959.
[2]Not protected prior to 1958.
[3]Not protected prior to 1961.
[4]Not protected prior to 1957.

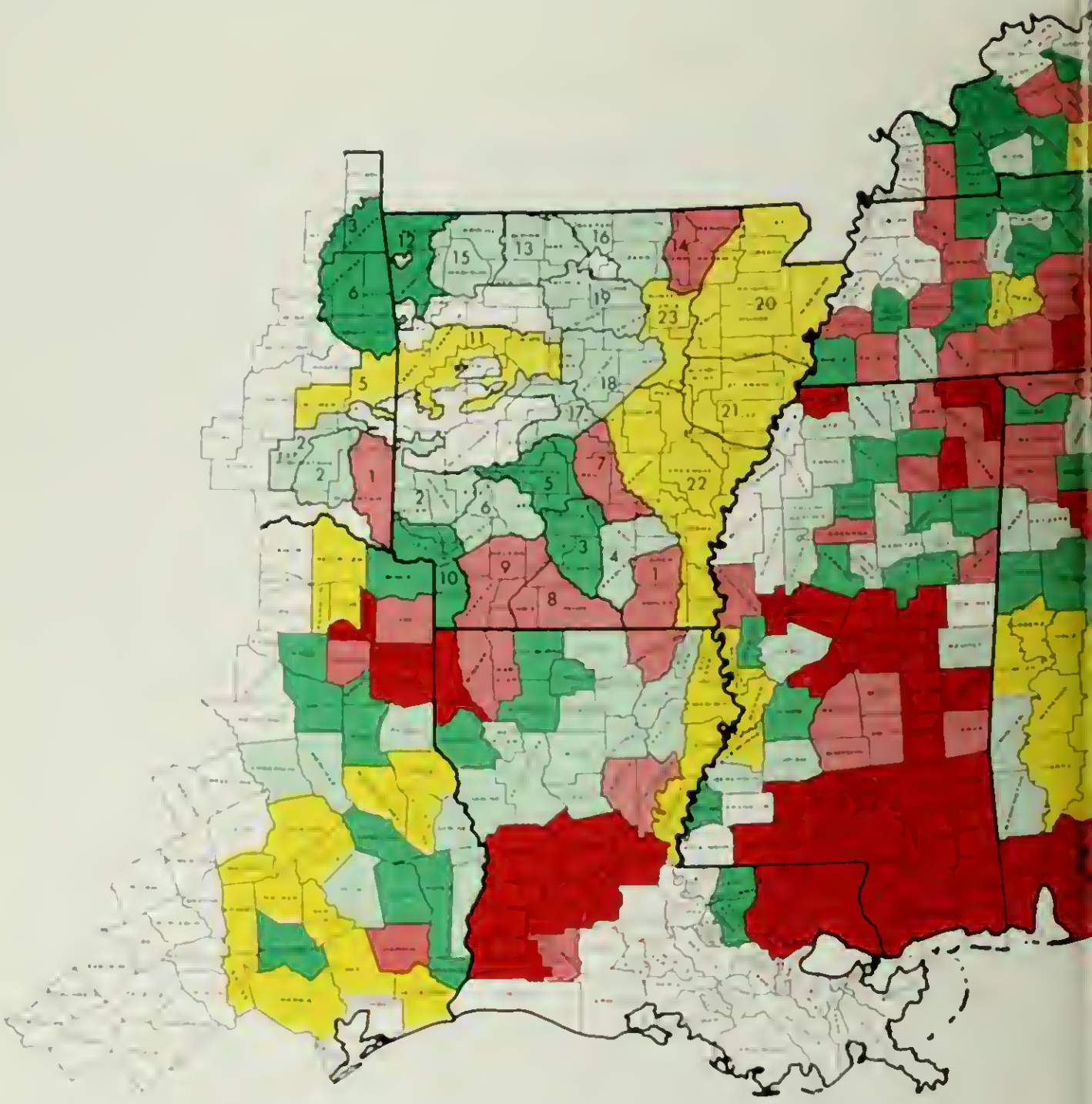
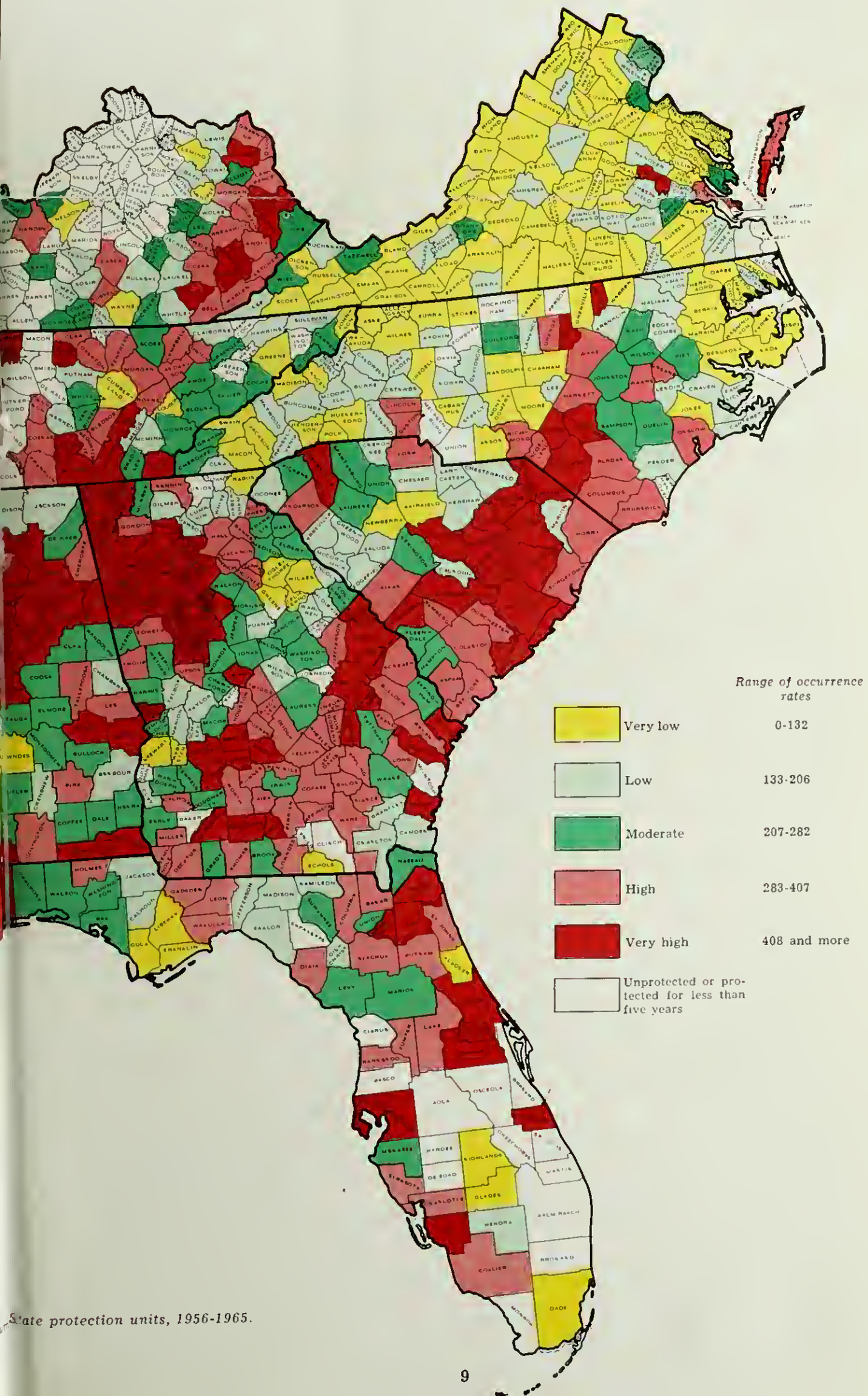


Figure 1.—Forest fire occurre



State protection units, 1956-1965.

Table 7.--*Louisiana*

Parish	Fires	Protected area	Av. fire rate	Rank in State	Parish	Fires	Protected area	Av. fire rate	Rank in State
	No.	*M acres*				*No.*	*M acres*		
Allen	5,730	3,535	1,621	38	Lincoln	512	1,829	280	22
Avoyelles	81	90	900	34	Livingston	7,858	3,202	2,454	41
Beauregard	6,451	6,745	956	35	Madison	148	2,909	51	2
Bienville	826	3,830	216	17	Morehouse	401	1,250	321	24
Bossier	1,055	3,548	297	23	Natchitoches	995	4,885	204	16
Caddo	1,637	2,963	552	30	Ouachita	561	2,848	204	16
Calcasieu	1,899	2,629	722	33	Rapides	2,896	5,452	531	31
Caldwell	431	2,951	146	5	Red River	249	1,452	171	10
Catahoula	296	910	325	26	Richland	294	1,535	192	12
Claiborne	799	3,021	264	21	Sabine	1,099	5,500	200	15
Concordia	170	3,105	55	4	St. Helena	3,708	2,120	1,749	40
De Soto	817	3,668	223	20	St. Tammany	6,280	4,275	1,469	37
E. Baton Rouge	122	550	222	19	Tangipahoa	3,965	3,694	1,073	36
E. Carroll	75	1,432	52	3	Tensas	111	2,444	45	1
E. Feliciana	371	1,691	219	18	Union	766	4,657	164	7
Evangeline	2,384	1,390	1,715	39	Vernon	2,764	5,158	536	32
Franklin	248	1,638	151	6	Washington	1,417	2,900	489	29
Grant	442	2,339	189	11	Webster	995	2,563	388	28
Jackson	520	3,134	166	8	W. Carroll	164	986	166	9
Jefferson Davis	65	200	325	27	Winn	891	4,516	197	14
La Salle	859	2,669	322	25					

Table 8.--*Mississippi*

County	Fires	Protected area	Av. fire rate	Rank in State	County	Fires	Protected area	Av. fire rate	Rank in State
	No.	*M acres*				*No.*	*M acres*		
Adams	302	1,300	232	19	Lee[2]	626	1,243	503	50
Alcorn	1,533	1,572	975	70	Leflore	284	1,672	169	9
Amite[1]	1,313	2,351	558	53	Lincoln	2,269	2,798	810	65
Attala	2,061	3,574	576	55	Lowndes	457	1,610	283	29
Benton	300	1,560	192	15	Madison	1,047	1,524	687	59
Calhoun	457	2,696	169	8	Marion	1,761	2,536	694	60
Carroll	785	3,096	253	23	Marshall	547	2,784	196	16
Chickasaw	511	2,176	234	20	Monroe	638	2,690	237	22
Choctaw	541	2,050	263	25	Montgomery	364	1,996	182	14
Claiborne	176	2,372	74	2	Neshoba[4]	822	1,432	574	54
Clarke	1,201	3,730	321	35	Newton	1,225	2,556	479	47
Clay[1]	195	1,170	166	7	Oktibbeha[1]	288	1,040	276	27
Copiah	578	3,802	152	5	Panola	305	2,112	144	4
Covington	1,523	1,954	779	63	Pearl River	2,777	4,110	675	58
De Soto	442	996	443	44	Perry	1,480	1,374	1,077	71
Forrest	2,893	1,752	1,651	73	Pike	1,262	1,790	705	61
George	2,291	2,426	944	69	Pontotoc	757	2,152	351	37
Greene	1,742	3,844	453	45	Prentiss	684	1,850	369	39
Grenada	493	1,722	286	30	Rankin	1,237	3,944	313	33
Hancock	2,188	2,732	800	64	Scott	648	2,196	295	31
Harrison	3,947	2,270	1,738	74	Sharkey	246	1,042	236	21
Hinds	621	2,284	271	26	Simpson[1]	766	1,937	395	40
Holmes	1,605	3,034	529	51	Smith	959	2,658	360	38
Humphreys[2]	523	885	590	56	Stone	1,064	1,998	532	52
Issaquena	178	1,870	95	3	Tallahatchie	384	2,252	170	10
Itawamba	840	2,638	318	34	Tate	287	1,582	181	13
Jackson	2,604	3,888	669	57	Tippah	647	1,948	332	36
Jasper	1,407	3,318	424	42	Tishomingo	946	2,252	420	41
Jefferson[2]	377	2,314	162	6	Union	436	1,682	259	24
Jefferson Davis	1,545	1,696	910	68	Walthall	712	1,440	494	49
Jones	2,292	2,980	769	62	Warren[2]	135	2,680	50	1
Kemper	663	3,768	175	11	Washington[3]	197	655	300	32
Lafayette	574	2,736	209	18	Wayne	1,768	3,672	481	48
Lamar[2]	3,932	2,398	1,639	72	Webster	371	2,084	178	12
Lauderdale	1,418	3,028	468	46	Winston[4]	620	1,460	424	43
Lawrence[1]	1,272	1,484	857	67	Yalobusha	531	1,916	277	28
Leake[3]	1,114	1,307	852	66	Yazoo	737	3,630	203	17

[1]Not protected prior to 1959.
[2]Not protected prior to 1957.
[3]Not protected prior to 1961.
[4]Not protected prior to 1960.

Table 9.--*North Carolina*

County	Fires	Protected area	Av. fire rate	Rank in State	County	Fires	Protected area	Av. fire rate	Rank in State
	No.	*M acres*				*No.*	*M acres*		
Alamance	230	1,330	172	53	Jackson	273	2,260	120	30
Alexander	148	873	169	50	Johnston	672	2,514	267	73
Alleghany	66	598	110	25	Jones	190	1,948	97	20
Anson	267	2,048	130	36	Lee	248	1,203	206	64
Ashe	77	1,355	54	3	Lenoir	196	1,273	153	45
Avery	170	923	184	60	Lincoln[2]	182	528	344	84
Beaufort	439	3,433	127	35	McDowell	291	1,628	178	56
Bertie	199	3,086	64	5	Macon	143	1,236	115	28
Bladen	1,256	4,292	292	77	Madison	186	1,497	124	33
Brunswick	1,323	4,436	298	80	Martin	189	2,021	93	17
Buncombe	479	2,691	178	55	Mitchell	174	892	195	63
Burke	352	2,008	175	54	Montgomery	248	2,161	114	26
Cabarrus	73	893	81	14	Moore	259	3,336	77	12
Caldwell	250	1,873	133	38	Nash	422	1,778	237	69
Camden	106	1,031	102	22	Northampton	266	2,000	133	39
Carteret	311	1,821	170	51	Onslow	940	3,014	311	81
Caswell[1]	136	1,119	121	31	Orange	462	1,564	295	78
Catawba	159	990	160	47	Pamlico	239	1,519	157	46
Chatham	401	3,463	115	27	Pasquotank	121	839	144	41
Cherokee	358	1,666	214	66	Pender	847	4,535	186	61
Chowan	80	638	125	34	Perquimans	92	1,012	90	16
Clay	90	593	151	44	Pitt	487	2,158	225	68
Cleveland[1]	145	708	181	58	Polk	103	1,092	94	19
Columbus	1,551	4,370	354	85	Randolph	383	3,262	117	29
Craven	490	2,870	170	52	Richmond	572	2,018	283	75
Cumberland	1,824	2,341	779	92	Robeson	1,957	2,938	666	91
Dare	125	1,913	65	6	Rowan	232	1,397	166	49
Davidson	322	1,702	189	62	Rutherford	171	2,120	80	13
Duplin	719	3,325	216	67	Sampson	930	3,779	246	71
Durham	590	1,169	505	88	Scotland	411	1,032	398	86
Edgecombe	294	1,631	180	57	Stanly	227	1,099	206	65
Franklin	247	1,833	134	40	Stokes	125	1,826	68	7
Gaston	419	1,025	407	87	Surry	133	2,082	63	4
Gates	120	1,601	74	11	Swain	77	623	123	32
Graham	143	591	241	70	Transylvania	216	1,328	162	48
Granville	186	2,131	87	15	Tyrrell	73	2,324	31	1
Greene	243	816	297	79	Vance	424	776	546	89
Guilford	474	1,786	265	72	Wake	1,037	3,099	334	82
Halifax	392	2,657	147	42	Warren	200	1,976	101	21
Harnett	651	2,232	291	76	Washington	108	1,487	72	10
Haywood	236	1,295	182	59	Watauga	91	976	93	18
Henderson	107	1,541	69	8	Wayne	548	1,609	340	83
Hertford	200	1,517	131	37	Wilkes	257	3,701	69	9
Hoke	460	714	644	90	Wilson	320	1,147	278	74
Hyde	152	2,842	53	2	Yadkin[1]	119	791	150	43
Iredell	187	1,738	107	24	Yancey	117	1,109	105	23

[1]Not protected prior to 1959.
[2]Not protected prior to 1960.

Table 10.--*Oklahoma*

District	Fires	Protected area	Av. fire rate	Rank in State
	No.	*M acres*		
1	2,855	8,760	325	6
2	1,235	7,470	165	3
2 (Expansion)[1]	261	1,883	138	2
3	1,396	5,580	250	4
5[1]	348	3,836	90	1
6	2,493	9,650	258	5

[1]Not protected prior to 1959.

Table 11.--*South Carolina*

County	Fires	Protected area	Av. fire rate	Rank in State	County	Fires	Protected area	Av. fire rate	Rank in State
	No.	*M acres*				*No.*	*M acres*		
Abbeville	247	1,732	143	5	Greenwood	339	1,944	174	9
Aiken	1,381	4,260	324	27	Hampton	661	2,486	266	20
Allendale	383	1,430	268	21	Horry	1,955	5,452	358	31
Anderson	549	1,814	303	25	Jasper	1,051	2,934	358	32
Bamberg	453	1,316	344	30	Kershaw	689	3,528	195	12
Barnwell	624	1,068	584	40	Lancaster	422	2,054	205	15
Beaufort	483	1,708	283	23	Laurens	542	2,514	216	17
Berkeley	2,464	4,000	616	41	Lee	563	1,122	502	35
Calhoun	217	1,256	173	8	Lexington	708	2,940	241	18
Charleston	1,301	2,700	482	34	Marion	452	2,258	200	13
Cherokee	235	1,322	178	10	Marlboro	1,005	1,556	646	42
Chester	363	2,606	139	4	McCormick	218	1,448	150	6
Chesterfield	587	3,200	183	11	Newberry	221	2,104	105	1
Clarendon	1,810	2,274	796	46	Oconee	510	2,534	201	14
Colleton	1,471	4,722	312	26	Orangeburg	2,448	3,306	740	45
Darlington	1,015	2,018	503	36	Pickens	505	1,956	258	19
Dillon	665	1,446	460	33	Richland	1,542	2,942	524	39
Dorchester	899	2,708	332	28	Saluda	212	1,564	136	3
Edgefield	292	1,770	165	7	Spartanburg	603	2,148	281	22
Fairfield	407	3,462	118	2	Sumter	1,372	2,104	652	43
Florence	2,104	2,936	717	44	Union	348	1,678	207	16
Georgetown	1,163	4,108	283	24	Williamsburg	2,181	4,260	512	38
Greenville	1,383	2,718	509	37	York	558	2,362	336	29

Table 12.--*Tennessee*

County	Fires	Protected area	Av. fire rate	Rank in State	County	Fires	Protected area	Av. fire rate	Rank in State
	No.	*M acres*				*No.*	*M acres*		
Anderson	404	1,207	334	52	Johnson	58	866	66	1
Benton	316	1,581	199	14	Knox	278	1,060	262	34
Bledsoe	648	1,889	343	54	Lawrence	824	1,860	443	68
Blount	259	1,072	241	26	Lewis	526	1,480	355	56
Bradley	235	998	235	24	Loudon[1]	25	265	94	3
Campbell	707	2,291	308	47	McMinn	229	1,300	176	13
Cannon[1]	182	460	395	63	McNairy	755	1,915	394	62
Carroll	381	1,267	300	45	Madison	440	1,170	376	58
Carter	183	768	238	25	Marion	1,581	2,534	623	72
Cheatham	289	1,235	234	23	Maury	477	1,097	434	67
Chester	184	880	209	17	Meigs[4]	97	617	157	10
Claiborne	258	1,646	156	9	Monroe[3]	319	1,318	242	27
Clay[2]	178	577	308	48	Montgomery	262	1,041	251	28
Cocke	310	1,154	268	35	Moore	93	312	298	44
Coffee	504	1,347	374	57	Morgan	861	2,897	297	43
Cumberland	444	3,603	123	5	Overton	432	1,515	285	40
Davidson	400	1,230	325	50	Perry	223	2,081	107	4
Decatur	168	1,265	132	6	Polk	488	728	670	73
Dickson	425	1,650	257	31	Putnam	198	1,291	153	8
Fayette	483	1,230	392	61	Rhea	510	1,222	417	66
Fentress	796	2,709	293	41	Roane	469	1,178	398	64
Franklin	626	1,878	333	51	Scott	689	2,981	231	21
Giles[3]	680	1,295	525	69	Sequatchie	495	1,414	350	55
Grainger	221	1,020	216	19	Sevier	364	1,352	269	36
Greene	93	1,010	92	2	Shelby	230	895	256	29
Grundy	1,058	1,917	551	71	Stewart	462	2,068	223	20
Hamilton	2,050	1,924	1,065	74	Sullivan	118	700	168	11
Hardeman	418	2,067	202	15	Sumner[4]	367	882	416	65
Hardin	641	2,242	285	39	Tipton	197	577	341	53
Hawkins	269	1,530	175	12	Unicoi	113	440	256	30
Haywood	254	906	280	38	Union	246	832	295	42
Henderson	390	1,420	274	37	Van Buren	320	1,370	233	22
Henry[3]	320	1,225	261	33	Warren	178	1,175	151	7
Hickman	1,039	2,722	381	60	Wayne	1,150	3,597	319	49
Houston	196	962	203	16	Weakley	260	845	307	46
Humphreys	611	2,341	260	32	White	260	1,236	210	18
Jackson	501	925	541	70	Williamson[2]	403	1,058	380	59

[1]Not protected prior to 1961.
[2]Not protected prior to 1959.
[3]Not protected prior to 1957.
[4]Not protected prior to 1958.

Table 13.--*Texas*

County	Fires	Protected area	Av. fire rate	Rank in State	County	Fires	Protected area	Av. fire rate	Rank in State
	No.	*M acres*				*No.*	*M acres*		
Anderson	432	3,106	139	19	Nacogdoches	453	4,296	105	8
Angelina	887	3,996	221	24	Newton	907	5,623	161	20
Bowie	654	2,844	229	25	Orange	392	1,397	280	32
Camp	146	312	467	38	Panola	480	3,577	134	17
Cass	1,456	3,568	407	35	Polk	841	6,143	136	18
Cherokee	749	4,524	165	21	Red River	276	2,610	105	9
Franklin[1]	36	305	118	15	Rusk	868	3,225	269	30
Gregg	210	913	230	26	Sabine	372	1,898	195	22
Grimes	57	1,231	46	3	San Augustine	252	2,232	112	12
Hardin	1,847	4,856	380	34	San Jacinto	301	2,727	110	11
Harris	60	745	80	5	Shelby	310	2,630	117	14
Harrison	1,567	3,092	506	39	Smith	483	1,814	266	29
Houston	322	3,911	82	6	Titus	52	399	130	16
Jasper	1,384	4,952	279	31	Trinity	326	2,976	109	10
Jefferson[1]	18	190	94	7	Tyler	1,258	5,451	230	27
Liberty	446	3,850	115	13	Upshur	514	1,561	329	33
Madison[1]	6	588	10	1	Walker	237	3,402	69	4
Marion	782	1,897	412	36	Waller	9	341	26	2
Montgomery	1,387	5,528	250	28	Wood[2]	256	1,184	216	23
Morris	241	550	438	37					

[1]Not protected prior to 1961.
[2]Not protected prior to 1960.

Table 14.--*Virginia*

County	Fires	Protected area	Av. fire rate	Rank in State	County	Fires	Protected area	Av. fire rate	Rank in State
	No.	*M acres*				*No.*	*M acres*		
Accomack	356	1,090	326	92	King William	33	1,310	25	4
Albemarle	480	2,800	171	73	Lancaster	58	560	103	47
Alleghany	95	1,150	82	29	Lee	246	1,270	193	80
Amelia	107	1,640	65	17	Loudoun	91	980	92	38
Amherst	304	1,660	183	77	Louisa	149	2,280	65	18
Appomattox	144	1,460	98	44	Lunenburg	144	2,010	71	24
Augusta	100	1,500	66	20	Madison	57	870	65	19
Bath	41	1,220	33	6	Mathews	81	300	270	90
Bedford	304	2,880	105	49	Mecklenburg	229	2,090	109	52
Bland	66	1,500	44	8	Middlesex	62	540	114	54
Botetourt	151	1,720	87	32	Montgomery	205	1,360	150	68
Brunswick	294	2,580	113	53	Nansemond	273	1,610	169	72
Buchanan	481	2,770	173	75	Nelson	244	2,060	118	57
Buckingham	192	2,830	67	21	New Kent	102	1,080	94	40
Campbell	218	2,200	99	45	Northampton	159	380	418	94
Caroline	274	2,110	129	61	Northumberland	97	750	129	62
Carroll	127	1,510	84	30	Nottoway	179	1,250	143	66
Charles City	120	870	137	65	Orange	131	1,430	91	37
Charlotte	157	2,090	75	26	Page	99	660	150	69
Chesterfield	416	2,190	189	79	Patrick	213	2,040	104	48
Clarke	5	350	14	1	Pittsylvania	237	4,060	58	16
Craig	30	600	50	11	Powhatan	59	1,300	45	9
Culpeper	105	1,160	90	35	Prince Edward	254	1,600	158	71
Cumberland	106	1,190	89	34	Prince George	280	1,190	235	85
Dickenson	235	1,770	132	64	Prince William	193	980	196	81
Dinwiddie	325	2,190	148	67	Pulaski	119	770	154	70
Essex	132	1,060	124	59	Rappahannock	59	650	90	36
Fairfax	286	1,380	207	83	Richmond	58	770	75	27
Fauquier	207	1,630	126	60	Roanoke	240	980	244	88
Floyd	74	1,090	67	22	Rockbridge	103	1,830	56	14
Fluvanna	105	1,210	86	31	Rockingham	48	1,360	35	7
Franklin	312	2,870	108	51	Russell	164	1,430	114	55
Frederick	43	1,410	30	5	Scott	158	1,620	97	43
Giles	107	1,130	94	39	Shenandoah	20	1,100	18	2
Gloucester	249	960	259	89	Smyth	101	990	102	46
Goochland	173	1,320	131	63	Southampton	181	2,530	71	25
Grayson	66	1,270	51	12	Spotsylvania	235	1,920	122	58
Greene	57	480	118	56	Stafford	238	990	240	86
Greensville	244	1,390	175	76	Surry	91	1,350	67	23
Halifax	301	3,120	96	42	Sussex	199	2,500	79	28
Hanover	410	2,080	197	82	Tazewell	443	1,840	240	87
Henrico	1,388	780	1,779	95	Warren	36	640	56	15
Henry	273	1,580	172	74	Washington	135	1,540	87	33
Highland	33	1,430	23	3	Westmoreland	96	890	107	50
Isle of Wight	221	1,190	185	78	Wise	393	1,700	231	84
James City	190	640	296	91	Wythe	50	980	51	13
King and Queen	77	1,560	49	10	York	146	420	347	93
King George	70	730	95	41					

SOUTHERN FOREST EXPERIMENT STATION

1970

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TREE-CHARACTER RELATIONS IN SOUTHERN HARDWOOD STANDS

W. M. Broadfoot [1]

SOUTHERN FOREST EXPERIMENT STATION

Site index and other characters of sweetgum are compared with those of green ash, eastern cottonwood, and cherrybark, Nuttall, water, and willow oaks growing close to and of the same age as the sweetgums.

During a comprehensive study of the relations between soil and site index for seven major southern hardwoods,[2] measurements were made on a number of plots that contained more than one of the test species in an even-aged overstory. Plots were selected to be representative of undisturbed hardwood stands in the Midsouth. Data presented here indicate the approximate relative performance of the species in terms of site index, basal area, diameter, number of potential 16-foot logs, log grade, tree bark vigor, and insect incidence.

Study trees were sweetgum *(Liquidambar styraciflua* L.), green ash *(Fraxinus pennsylvanica* Marsh.), eastern cottonwood *(Populus deltoides* Bartr.), and water *(Quercus nigra* L.), willow *(Q. phellos* L.), Nuttall *(Q. nuttallii* Palmer), and cherrybark *(Q. falcata* var. *pagodaefolia* Ell.) oaks. Because it occurs commonly on a wide variety of sites, sweetgum was used as the reference species in the comparisons.

PROCEDURES

Plots covered 1/5 acre and had uniform soil conditions. The stands on them were well stocked, even aged, and had not been recently logged or burned. Minimum stocking was 70 square feet of basal area in trees 6 inches or larger in diameter. To minimize the effects of errors in site curves, site index was estimated only from trees that were within 10 years of index age. Measurements were made only on dominant and codominant trees.

Total height, d.b.h., and age at breast height were measured. Estimates were made of number of actual or potential 16-foot saw logs to the nearest ½ log, grade of the bottom log in the tree, tree vigor, and incidence of insect attack. Vigor was estimated by a method des-

[1] Stationed at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Miss., in cooperation with the Mississippi Agricultural Experiment Station and the Southern Hardwood Forest Research Group.

[2] Broadfoot, W. M. Problems in relating soil to site index for southern hardwoods. Forest Sci. 15: 354-364. 1969.

cribed by Guttenberg and Putnam.[3] A relative scale was prepared to classify severity of insect attacks: 1 = no attacks, 2 = one to five insect holes or scars on the log grading face, and 3 = six or more insect holes or scars on the log grading face.

Between 10 and 20 sample trees of each species from a variety of soils were felled and sectioned to establish partial height-over-age curves for estimating 50-year heights of trees above or below this age (the index age for cottonwood was 30 years). On each sectioned tree, age was counted at intervals of 8 feet from a 1-foot stump to the top. A large number of seedlings and saplings were cut to determine the time required for each species to reach breast height. This value was added to age at d.b.h. to get total age.

Individual tree characters were compared only on the plots that contained sweetgum. Data were compiled into four sweetgum site-index classes: less than 85 feet, 85 through 94 feet, 95 through 104 feet, and 105 feet or more. Tree characters for the seven species were compared within these classes.

Site-index relations were computed by regression analysis. The site index of each species was related to that of sweetgum and vice versa.

RESULTS

Species combinations with sweetgum are presented by sweetgum site-index class in table 1. The most frequent combination was water oak and sweetgum; the least frequent was cottonwood and sweetgum. There were no stands of sweetgum and cottonwood where sweetgum site index was less than 85 feet. Where sweetgum and green ash were growing together, sweetgum site index was usually low. Sweetgum apparently does not grow well on the poorly aerated soils where green ash is common.

Table 1.—*Number of stands in which each species occurred with sweetgum, by sweetgum site-index class*

Sweetgum site-index class	Cotton-wood	Cherry-bark oak	Water oak	Willow oak	Nuttall oak	Green ash
	– – – – – *Number of stands* – – – – –					
Less than 85 feet	0	17	15	12	9	5
85-94 feet	6	25	29	26	19	13
95-104 feet	10	48	47	28	20	20
105 feet plus	8	17	23	11	8	9
All site classes	24	107	114	77	56	47

The relations among site index of sweetgum and those of the other six species are shown in figures 1 through 6. The regression equations presented are not recommended for estimating site index. They are meant only to

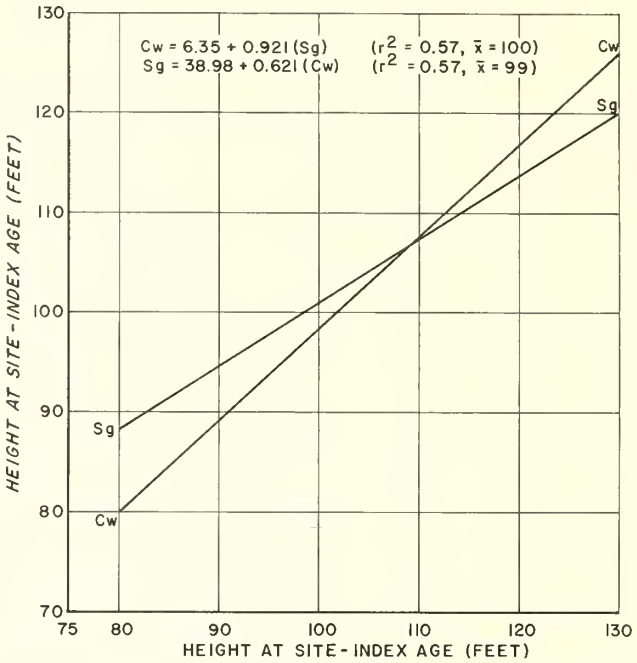

Figure 1.—*Site-index relations between sweetgum (Sg) and cottonwood (Cw) (N = 24).*

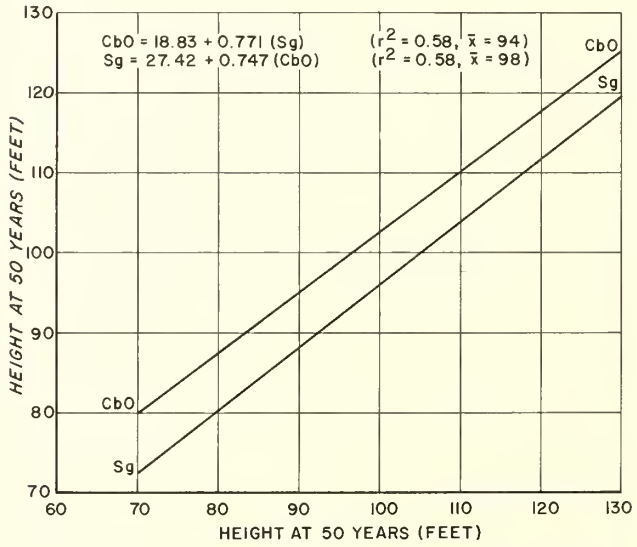

Figure 2.—*Site-index relations between sweetgum (Sg) and cherrybark oak (CbO) (N = 107).*

[3] Guttenberg, S., and Putnam, J. A. Financial maturity of bottomland red oaks and sweetgum. USDA Forest Serv. South. Forest Exp. Sta. Occas. Pap. 117, 24 pp. 1951.

show relations that existed on the study plots. The squared correlation coefficient was highest between sweetgum and cherrybark oak and lowest between sweetgum and willow oak.

To compare site indexes from the regression lines, enter the known site index on X-axis and read up to the site-index line of the species being compared to the known. To find the value sought, read across to the Y-axis from the point on the site-index line. For example, assume site index for sweetgum is 100 feet (fig. 1). To get cottonwood site index on the same site, enter 100 on X-axis to cottonwood line, and read Y-axis at 98.4 To get sweetgum site index from cottonwood, enter cottonwood value on X-axis to sweetgum line, then read across to the Y-axis. Thus, if cottonwood site index is 100, sweetgum site index is 101.1.

The figures illustrate at least four striking results. The first is the remarkable growth potential of cottonwood on good sites. As mentioned previously, it did not appear on poor sweetgum sites. On the best sweetgum sites it grew about 5 feet taller in 30 years than sweetgum did in 50 years (fig. 1). Second, cherrybark oak consistently outgrew sweetgum on all sites by about 5 feet in 50 years (fig. 2). The difference was slightly greater on the low-quality sweetgum sites than on the better sites. Third, green ash grew considerably slower than sweetgum on all sites (fig. 6). The average difference was about 12 feet on all site classes. Fourth, site indexes of sweetgum and water, willow, and Nuttall oaks were about the same when the species occurred together.

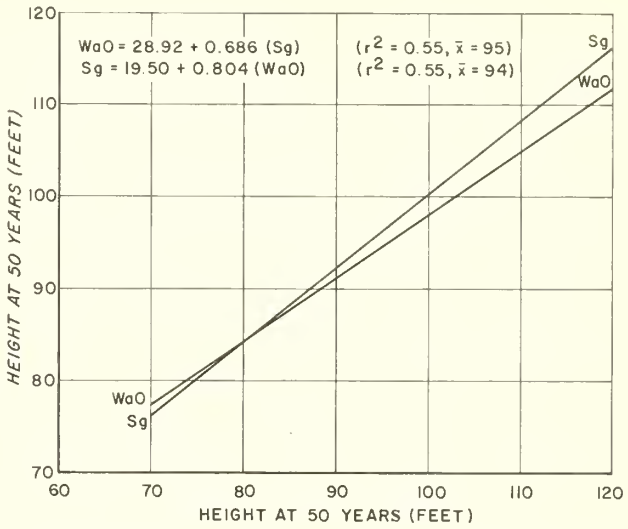

Figure 3.—*Site-index relations between sweetgum (Sg) and water oak (WaO) (N = 114).*

Table 2.—*Average basal areas of stands in which each species combination occurred, by sweetgum site-index class*

Sweetgum site-index class	Species occurring with sweetgum					
	Cottonwood	Cherrybark oak	Water oak	Willow oak	Nuttall oak	Green ash
	Square feet					
Less than 85 feet						
Mean	.	122	124	115	121	139
Range		69-159	66-159	66-153	100-153	118-165
Std. deviation	. . .	23	23	27	17	19
85-94 feet						
Mean	166	123	124	129	143	137
Range	110-243	90-179	87-198	87-243	87-243	87-198
Std. deviation	46	27	30	38	43	32
95-104 feet						
Mean	152	128	132	137	137	146
Range	108-210	84-228	84-228	89-226	87-210	98-205
Std. deviation	38	29	31	33	38	34
105 feet plus						
Mean	148	126	130	145	157	132
Range	121-174	89-163	89-201	65-330	92-330	110-174
Std. deviation	34	25	29	72	74	19
All site classes						
Mean	154	125	128	132	140	140
Std. deviation	34	27	29	42	44	30

Stand basal areas for all species combinations with sweetgum are shown in table 2. Several stands had exceptionally high basal areas. The averages ranged from 125 square feet for the sweetgum-cherrybark oak stands to 154 square feet for the sweetgum-cottonwood.

All species grew faster in diameter as sweetgum site improved (table 3). Best diameter growth was made by cottonwood, followed by cherrybark, water, Nuttall, and willow oak, and green ash. In stands where sweetgum site index was less than 85 feet, sweetgum diameter

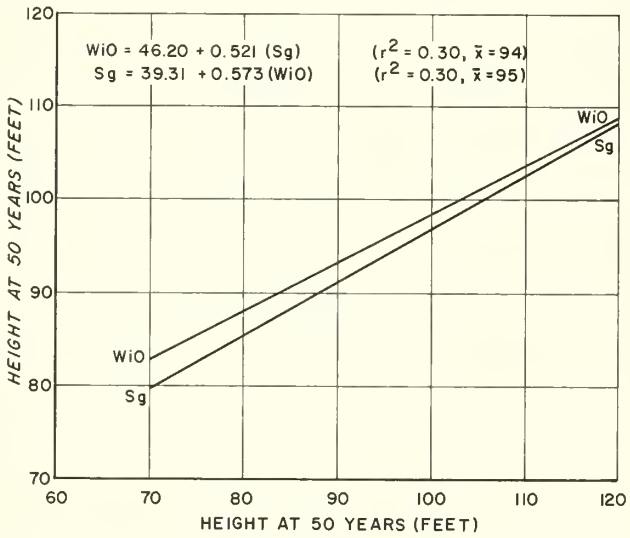

Figure 4.—*Site-index relations between sweetgum (Sg) and willow oak (WiO) (N = 77).*

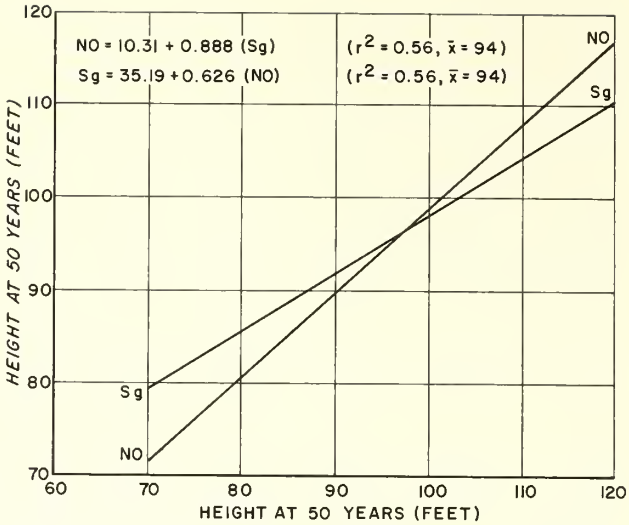

Figure 5.—*Site-index relations between sweetgum (Sg) and Nuttall oak (NO) (N = 56).*

growth was about 30 percent less than that of all oaks, but 30 percent more than ash. In the better sweetgum site classes, its diameter growth in 10 years averaged about 20 percent less than cottonwood and the oaks, and 5 to 10 percent more than green ash.

Sweetgums had more merchantable logs on all sites than water oak, Nuttall oak, and ash (table 4). The differences in sweetgum-green ash stands amounted to about ½ log on poor sites and 1 log on good sites. Log lengths in cottonwood and willow oak were not compared with those in sweetgum. Lengths of merchant-

Table 3.—*Relative 10-year diameter growths of sweetgum and each of six species, by sweetgum site-index class (inches)*

Sweetgum site-index class	Species combination											
	Sweet-gum	Cotton-wood	Sweet-gum	Cherry-bark oak	Sweet-gum	Water oak	Sweet-gum	Willow oak	Sweet-gum	Nuttall oak	Sweet-gum	Green ash
Less than 85 feet												
Mean	.	.	2.5	3.4	2.5	3.1	2.8	3.4	2.7	3.4	2.9	2.2
Range	.	.	1.8-3.0	2.5-5.2	1.8-3.0	2.3-3.6	2.3-3.6	2.4-4.5	2.3-3.2	2.5-4.2	2.3-3.4	2.0-2.8
Std. deviation	.	.	.4	.7	.5	.4	.4	.6	.3	.6	.4	.4
85-94 feet												
Mean	3.4	4.2	3.0	3.9	3.0	3.8	3.5	3.8	3.2	3.6	3.2	2.9
Range	2.8-4.5	3.5-5.0	2.2-4.5	2.6-7.0	2.2-3.9	2.5-6.0	2.3-4.4	2.3-5.5	2.5-3.7	2.4-4.6	2.5-4.4	1.5-4.0
Std. deviation	.6	.5	.5	.9	.4	.7	.4	.8	.3	.6	.5	.8
95-104 feet												
Mean	3.7	5.0	3.2	4.0	3.3	3.8	3.2	3.7	3.4	3.9	3.3	2.9
Range	3.1-4.7	3.6-6.4	2.3-4.5	2.3-5.5	2.3-4.5	2.7-6.0	2.3-4.5	3.0-4.9	2.3-4.5	2.7-5.1	2.3-4.2	2.0-4.0
Std. deviation	.5	.9	.6	.7	.5	.6	.6	.5	.6	.7	.5	.6
105 feet plus												
Mean	4.0	5.6	3.8	5.0	3.9	4.5	3.8	4.0	3.6	4.3	3.4	3.1
Range	3.6-4.3	4.4-8.0	2.9-4.7	3.9-6.7	2.9-4.7	2.7-5.6	2.5-4.7	2.9-4.6	2.6-4.7	3.9-5.3	2.6-4.0	1.8-3.8
Std. deviation	.3	1.2	.5	.8	.4	.7	.6	.5	.6	.5	.5	.7
All site classes												
Mean	3.7	5.0	3.2	4.0	3.2	3.8	3.3	3.7	3.2	3.8	3.2	2.9
Std. deviation	.5	1.0	.6	.9	.6	.8	.7	.6	.5	.6	.5	.7

able logs were about the same for sweetgum and cherrybark oak on all site classes.

Log grade was consistently better for all species on the best sites (table 5). Sweetgum's improvement was the most pronounced with increasing site quality, while the least influenced was Nuttall oak. On the poor sweetgum sites, only water oak had log grades as poor as sweetgum's. With increase in site class, sweetgum log grade became better than all other species except cherrybark oak and cottonwood.

Ash vigor was the same on the poorest sweetgum sites as it was on the best (table 6). Vigor of all other species increased with site quality, though improvement in Nuttall oak was slight. The lack of improvement in ash and the small improvement in Nuttall vigor are probably due

Table 4.—*Average numbers of merchantable 16-foot logs produced by sweetgum and four other species, by sweetgum site-index class*

Sweetgum site-index class	Species combination							
	Sweetgum	Cherrybark oak	Sweetgum	Water oak	Sweetgum	Nuttall oak	Sweetgum	Green ash
Less than 85 feet								
Mean	2.6	2.6	2.6	2.6	2.3	2.2	2.4	2.1
Range	2.0-3.0	1.8-3.0	2.0-3.0	1.5-3.0	2.0-2.8	2.0-2.8	2.2-2.5	1.8-2.5
Std. deviation	.4	.4	.4	.6	.3	.3	.2	.4
85-94 feet								
Mean	2.5	3.0	2.6	2.6	2.4	2.2	2.9	2.5
Range	1.2-3.2	2.5-3.8	1.2-3.5	2.0-3.0	1.2-3.0	2.0-2.5	2.5-3.2	2.0-3.0
Std. deviation	.8	.5	.7	.3	.6	.2	.2	.4
95-104 feet								
Mean	3.0	2.6	3.0	2.7	3.1	3.0	3.1	2.4
Range	2.2-4.0	2.0-3.5	2.2-4.0	2.0-3.5	2.5-3.8	2.5-3.5	2.5-3.5	2.0-3.5
Std. deviation	.4	.5	.5	.4	.4	.4	.3	.5
105 feet plus								
Mean	3.2	3.1	2.9	2.4	3.5	3.0	3.5	2.5
Range	3.0-3.5	3.0-3.5	2.5-3.0	2.0-3.0	3.5-3.5	3.0-3.0	3.5-3.5	2.5-2.5
Std. deviation	.3	.2	.2	.4	.0	.0	.0	.0
All site classes								
Mean	2.8	2.8	2.8	2.6	2.6	2.5	2.9	2.4
Std. deviation	.5	.5	.6	.4	.6	.5	.4	.4

Table 5.—*Average grades*[1] *of butt logs produced by sweetgum and six other species, by sweetgum site-index class*

Sweetgum site-index class	Species combination											
	Sweetgum	Cottonwood	Sweetgum	Cherrybark oak	Sweetgum	Water oak	Sweetgum	Willow oak	Sweetgum	Nuttall oak	Sweetgum	Green ash
Less than 85 feet												
Mean	.	.	2.5	2.0	2.5	2.5	2.5	2.3	2.4	2.1	2.5	2.4
Range	.	.	2.0-3.0	1.0-3.0	2.0-3.0	1.0-3.0	2.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	2.0-3.0	2.0-3.0
Std. deviation	.	.	.5	.7	.5	.6	.5	.6	.6	.7	.5	.5
85-94 feet												
Mean	2.3	2.3	2.2	1.8	2.2	2.0	2.2	2.2	2.3	2.0	1.9	2.2
Range	1.5-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.5-3.0	1.0-3.0	1.0-3.0	1.0-3.0
Std. deviation	.6	.8	.5	.5	.5	.6	.6	.6	.5	.6	.5	.6
95-104 feet												
Mean	2.0	1.7	1.9	1.6	1.9	2.0	1.9	1.9	2.0	1.8	1.8	2.0
Range	1.0-3.0	1.0-2.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0
Std. deviation	.6	.5	.5	.5	.6	.5	.5	.6	.4	.5	.6	.7
105 feet plus												
Mean	1.6	1.5	1.8	1.5	1.9	2.0	1.6	1.8	1.6	1.9	1.7	1.8
Range	1.0-2.0	1.0-2.0	1.0-3.0	1.0-2.0	1.0-3.0	1.0-3.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0
Std. deviation	.4	.5	.5	.5	.5	.5	.4	.4	.5	.3	.5	.5
All site classes												
Mean	2.0	1.8	2.0	1.7	2.0	2.1	2.0	2.0	2.1	1.9	1.9	2.1
Std. deviation	.6	.6	.5	.6	.6	.6	.6	.6	.6	.5	.6	.6

[1] Logs were graded 1, 2, or 3 for their quality for production of standard lumber. Grade 1 is best.

Table 6.—*Average tree vigors* [1] *for sweetgum and six other species, by sweetgum site-index class*

Sweetgum site-index class	Species combination											
	Sweet-gum	Cotton-wood	Sweet-gum	Cherry-bark oak	Sweet-gum	Water oak	Sweet-gum	Willow oak	Sweet-gum	Nuttall oak	Sweet-gum	Green ash
Less than 85 feet												
Mean	..	...	2.3	1.8	2.5	1.9	2.1	2.1	2.1	1.8	1.8	1.8
Range	.	.	1.5-3.0	1.0-3.0	2.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.5-3.0	1.0-2.0	1.5-2.0	1.0-2.0
Std. deviation	..	.	.5	.7	.5	.6	.5	.5	.5	.5	.3	.5
85-94 feet												
Mean	1.7	2.0	2.1	1.6	2.0	1.7	2.0	1.7	1.8	1.5	1.6	1.8
Range	1.0-2.0	1.0-3.0	1.0-3.0	1.0-2.5	1.0-3.0	1.0-3.0	1.0-3.0	1.0-2.5	1.0-3.0	1.0-2.0	1.0-2.0	1.0-3.0
Std. deviation	.5	.6	.5	.5	.6	.6	.4	.5	.6	.5	.5	.7
95-104 feet												
Mean	1.4	1.4	1.6	1.6	1.6	1.5	1.7	1.6	1.5	1.4	1.5	1.8
Range	1.0-2.0	1.0-2.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-2.0	1.0-3.0	1.0-3.0	1.0-3.0
Std. deviation	.4	.5	.6	.6	.6	.5	.5	.6	.5	.6	.6	.5
105 feet plus												
Mean	1.1	1.6	1.2	1.5	1.2	1.2	1.5	1.4	1.4	1.6	1.2	1.8
Range	1.0-2.0	1.0-3.0	1.0-2.0	1.0-3.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-3.0	1.0-2.0	1.0-3.0
Std. deviation	.4	.6	.4	.6	.4	.4	.5	.5	.5	.7	.5	.5
All site classes												
Mean	1.4	1.6	1.8	1.6	1.7	1.6	1.8	1.7	1.6	1.5	1.5	1.8
Std. deviation	.5	.8	.6	.6	.7	.6	.5	.6	.6	.6	.5	.6

[1] 1 = high vigor, 2 = medium, and 3 = low.

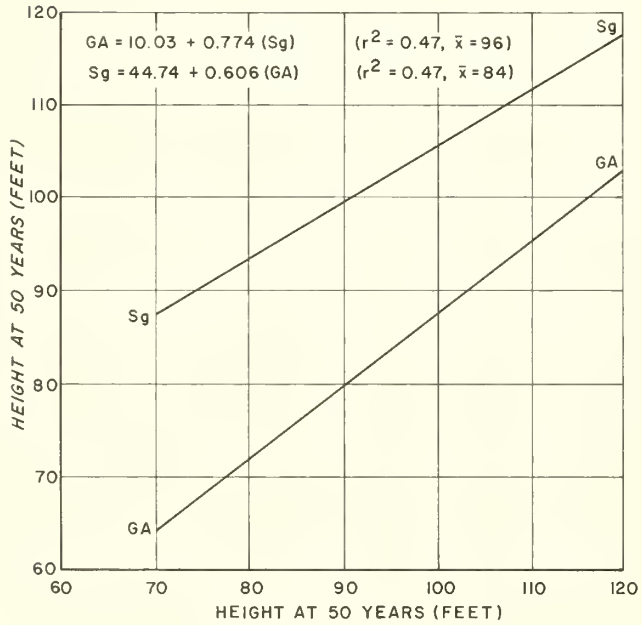

Figure 6.—
Site-index relations between sweetgum (Sg) and green ash (GA) (N = 47).

to the affinity of these species for wet sites, where sweetgum grows poorly. In general, oak vigor was better than sweetgum on poor sites, but less, or about the same, on the best sites.

Insect incidence was high on all the oaks on the poorest sweetgum sites. Damage in cherry-bark and water oaks declined rapidly as site quality increased (table 7). Attacks on other species did not appear to be related to sweetgum site class.

Table 7.—*Average insect incidence*[1] *on trunks of sweetgum and six other species, by sweetgum site-index class*

Sweetgum site-index class	Species combination											
	Sweetgum	Cottonwood	Sweetgum	Cherrybark oak	Sweetgum	Water oak	Sweetgum	Willow oak	Sweetgum	Nuttall oak	Sweetgum	Green ash
Less than 85 feet												
Mean	.	.	1.0	1.3	1.0	1.7	1.0	1.5	1.1	1.5	1.0	1.0
Range	.	..	1.0-1.0	1.0-3.0	1.0-1.0	1.0-3.0	1.0-1.5	1.0-3.0	1.0-1.5	1.0-3.0	1.0-1.0	1.0-1.0
Std. deviation	..	...	.0	.6	.0	.6	.2	.7	.2	.7	.0	.0
85-94 feet												
Mean	1.0	1.3	1.1	1.1	1.1	1.3	1.5	1.6	1.0	1.2	1.1	1.2
Range	1.0-1.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-2.0	1.0-2.0	1.0-3.0	1.0-3.0
Std. deviation	.0	.5	.3	.3	.3	.6	.7	.6	.3	.4	.3	.6
95-104 feet												
Mean	1.0	1.2	1.0	1.1	1.0	1.3	1.0	1.4	1.0	1.4	1.0	1.0
Range	1.0-1.0	1.0-2.0	1.0-1.0	1.0-2.0	1.0-1.0	1.0-3.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-1.0	1.0-2.0
Std. deviation	.0	.4	.0	.3	.0	.5	.2	.5	.2	.5	.0	.3
105 feet plus												
Mean	1.1	1.5	1.1	1.1	1.0	1.1	1.1	1.3	1.0	1.4	1.0	1.0
Range	1.0-1.5	1.0-2.0	1.0-2.0	1.0-2.0	1.0-1.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-1.0	1.0-1.0
Std. deviation	.2	.5	.3	.3	.0	.3	.3	.5	.2	.5	.0	.0
All site classes												
Mean	1.1	1.3	1.0	1.1	1.0	1.3	1.2	1.4	1.1	1.3	1.0	1.1
Std. deviation	.2	.5	.2	.4	.2	.5	.4	.5	.3	.5	.3	.4

[1] 1 = no evidence of attack, 2 = moderate attack, and 3 = heavy attack.

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GROWTH AND YIELD OF A MIXED LOBLOLLY-SLASH PINE PLANTATION

Eugene Shoulders [1]

SOUTHERN FOREST EXPERIMENT STATION

Loblolly and slash pines grew at approximately equal rates during 15 years of management when allowance was made for initial differences in average diameter at age 23. Overall growth averaged 151 cubic feet per acre per year and was unaffected by favoring one species over the other in thinnings to 85 square feet of basal area at 5-year intervals. The two species appear to be equally well suited to short rotation management on good Coastal Plain soils in central and southwest Louisiana.

Loblolly *(Pinus taeda* L.) and slash pines *(P. elliottii* Engelm.) are the most widely planted pines throughout the South Atlantic and Lower Gulf Coastal Plains. A landowner's choice of one or the other to regenerate a particular tract is largely empirical, as research has provided only meager information on long-term performance of the two species in managed plantations on a variety of sites.

A mixed planting of loblolly and slash pines in central Louisiana presented an opportunity to compare growth and yields of both species in close proximity on a good site, and to observe growth of slash pine in a region where the species is not native but has been extensively introduced.

THE PLANTATION

The plantation is on a gently sloping ancient river terrace in central Louisiana. Soil is Muskegee silt loam. Surface and internal drainage are fair to good. Site index averages 94 feet for both loblolly and slash pines.[2]

Three adjacent rows of each species were planted alternately throughout the stand; trees were spaced at 6-foot intervals in rows 8 feet apart. Loblolly seed was from northern Louisiana and slash seed from the southeastern part of the State.

The site, which was cutover longleaf land with a dense stand of native grasses, received no preplanting treatment. The plantation was never burned and had not been thinned when the study began. Of the two species, slash pine

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[2] Site index at age 50. These estimates are based on heights of dominant and codominant trees at age 38. Loblolly site indexes were read from curves for sites with poorly aerated subsoils (4) and slash indexes from curves (3).

grew much taller initially, probably because tip moth curtailed early height growth of loblolly.

The first comprehensive inventory of the plantation at age 23 revealed that it then contained 289 trees 3.6 inches d.b.h. and larger per acre; basal area was 122 square feet, and volume, 2,479 cubic feet inside bark (i.b.), or 33 standard rough cords, per acre. Only a few trees smaller than 3.6 inches in diameter were present.

Dominant and codominant trees averaged 62 feet in height for loblolly and 61 feet for slash. Potential crop trees averaged 11.0 feet of clear bole for loblolly, and 11.5 feet for slash. Despite a slower start, loblolly pines usually excelled in other characteristics at age 23. They contained 72 percent of the stand volume and 57 percent of the basal area. They were more numerous (156 vs. 133 stems per acre) and were 0.4 inch larger in average diameter than slash pines. Less than 1 percent of loblolly survivors had fusiform rust cankers on the main stem, whereas 18 percent of the slash survivors had trunk infections. Top breakage from a 1951 ice storm averaged 24 percent for loblolly and 32 percent for slash pine.

TREATMENTS

Beginning at age 23, three thinning regimes were imposed on the plantation. Loblolly was favored in one treatment and slash in another. In the third, neither species was given preference. The intent was to increase the proportion of the favored species without creating large openings in the crown canopy or introducing large differences in residual stocking. All plots were thinned to 85 $\pm$ 4 square feet of basal area per acre, thus encouraging diameter growth without reducing volume increment unduly. Cutting was on a 5-year cycle.

The first thinning, essentially an improvement cut, removed mostly defective, deformed, diseased, and seriously suppressed trees of both species. In other choices between trees of the same species, high-quality loblolly codominants were favored over rough dominants, and slash dominants were usually preferred over codominants and intermediates. Selections between adjacent loblolly and slash stems were always in favor of the preferred species if competing individuals did not differ greatly in size and vigor. Such selections were more common in the second and third than in the first thinning.

Treatments were replicated three times in a completely randomized design. Plots were 0.212 acre in size and contained six rows each of both species. A 24-foot or wider isolation strip surrounded individual plots.

Diameter, merchantable height to 3-inch (i. b.) top, and form class of all trees larger than 3.5 inches d.b.h. were measured at 5-year intervals. Individual tree volumes were obtained from form-class tables *(2)*. Total height, length of clear bole, and crown class were recorded for permanent sample trees to determine site index, periodic height growth, and changes in stem quality.

RESULTS

Managed growth.—Despite considerable changes in species composition and average diameter of the individual species due to treatment, loblolly and slash trees of equal size grew in volume at similar rates during the 15 years of management. One criticism often voiced against introducing slash pine west of the Mississippi is that its growth rate may be high for a few years and then decline rapidly. These results indicate no such trend.

Species preference in the treatments did not affect total gross growth of the stand, which averaged 151 cubic feet per acre per year during the 15-year period (table 1). Mortality was light, averaging only 7 cubic feet per acre per year, and was not associated with management alternatives.

Gross annual volume growth for all treatments averaged 149 cubic feet per acre in the first, 178 cubic feet in the second, and 125 cubic feet in the third 5-year period. Growth was significantly better in the second than in the first or third period. A similar trend was apparent in height growth of permanent sample trees. Whether these data indicate a culmination and subsequent slowing of managed growth due to age of the stand or a response to available soil moisture during the growing season is uncertain. Probably both contributed.

Basal area growth declined as the stand aged. Like volume and height growth it fell off drastically in the third period.

Table 1.—*Periodic annual growth per acre*

Item	Growth period (years)			
	23-28	28-33	33-38	Total 23-38
Volume		**CUBIC FEET**		
Loblolly	88	110	79	93
Slash	61	68	46	58
Both	149	178	125	151
Basal area		**SQUARE FEET**		
Loblolly	2.89	2.33	1.53	2.25
Slash	1.95	1.88	.94	1.59
Both	4.84	4.21	2.47	3.84
Diameter		**INCHES**		
Loblolly	0.29	0.29	0.18	0.25
Slash	.22	.25	.15	.21
Both	.26	.27	.17	.23
Height		**FEET**		
Loblolly	1.48	1.88	1.20	1.52
Slash	1.68	1.72	1.08	1.49
Both	1.58	1.80	1.14	1.51

Diameter growth of all residual trees averaged 0.26 inch per year in the first period, 0.27 inch per year in the second, and 0.17 inch per year in the third. Average stand diameter was increased an additional 1.2 inches by removing small stems in the three thinnings. Over the 15-year period, stand diameter went from 8.8 to 13.5 inches.

The loblolly component of the stand grew 0.03 to 0.07 inch per year faster than the slash. But it declined more in average diameter growth than did slash: the difference in annual growth between the first and third periods was 0.11 inch for loblolly and 0.07 inch for slash pine.

Contribution of the two species to volume growth depended on their residual basal areas and on their average diameters after the initial thinning. Overall, loblolly grew 21 percent more volume per square foot of residual basal area than slash pine. This difference was statistically significant. Subsequent analyses showed that the difference was due to average diameter of the trees after the first thinning. Why loblolly excelled in diameter at age 23 is not known and records are insufficient to determine when the difference developed. It may be that ice or fusiform rust retarded or killed more large dominant slash than loblolly during the early years.

Species composition.—The degree to which species composition was changed by three thinnings varied by treatment. Where loblolly was preferred, it comprised 74 percent of the basal area at age 38 as against 65 percent before the initial thinning. Loblolly stems contained 76 percent of the standing volume at age 38, or 13 percentage points more than at age 23. Standing volume in loblolly pine increased substantially during the 15 years, but slash volume remained fairly constant.

Species composition changed little in the other treatments. On plots where slash pine was favored, loblolly basal area and volume percentages were reduced (and slash percentages were increased) 4 and 1 percentage points. Volume and basal area were about equally divided between the two species at age 38. On plots where the two species were given equal preference, loblolly comprised 55 percent of the basal area and 56 percent of the volume at age 38. It had contained 55 percent of the basal area and 53 percent of the volume at age 23. The proportion of slash pine could not be greatly increased in these treatments without creating large openings in the canopy or retaining heavily damaged or diseased trees. In each of these treatments, total standing volume of both species increased with age, especially during the first two periods.

Total yield.—Total yield to age 38, including mortality after age 23, averaged 4,739 cubic feet (i.b.), or 62 standard rough cords, per acre (table 2). About one-third of the total

Table 2.—*Yields per acre*

Treatment	Stand age (years)			
	23	28	33	38
	Cubic feet			
Leave				
Loblolly	996	1,143	1,456	1,851
Slash	791	899	962	1,182
Both	1,787	2,042	2,418	3,033
Cut [1]				
Loblolly	390	684	921	921
Slash	303	499	777	785
Both	693	1,183	1,698	1,706
Total				
Loblolly	1,386	1,827	2,377	2,772
Slash	1,094	1,398	1,739	1,967
Both	2,480	3,225	4,116	4,739

[1] Including mortality after age 23.

was removed in the three thinnings, leaving a residual stand of 3,034 cubic feet, or 40 cords per acre. Loblolly pine comprised 68 percent and slash pine 32 percent of the gross yield where loblolly was favored. The two species yielded about equal volumes in the other treatments.

Mean annual growth, excluding mortality before the first thinning, averaged 108 cubic feet per acre to age 23, 115 cubic feet to age 28, and 125 cubic feet to ages 33 and 38. Species preference did not affect overall growth rates. In general, loblolly and slash growth rates were proportional to residual basal areas and average diameters.

Stem quality.—Yields of clear wood are markedly influenced by natural pruning and by stem defects due to fusiform rust cankers. The two species displayed remarkably similar trends in natural pruning. By age 38, loblolly sample trees had developed an average clear length of 29.1 feet—1.7 feet more than slash. In earlier inventories slash had equalled or surpassed loblolly in clear length, but differences were always small.

Fusiform cankers on the main bole accounted for the major differences between species in stem quality. All cankered loblolly were removed or had died by age 33, whereas at age 38 many infected slash pines remained. They comprised 5 percent of merchantable-sized slash stems where loblolly was favored, 10 percent where both species were given equal treatment, and 22 percent where slash was preferred. While most poor-risk stems had been cut, the proportion of cankered slash stems where slash was favored was as high as it had been at age 23. In addition to reflecting differences in quality, these data illustrate that cankered stems must sometimes be retained in young slash pine plantations in the West Gulf Region if reasonably uniform spacing is to be maintained. This policy was successfully followed in this study without increasing natural mortality of merchantable stems.

CONCLUSION

Perhaps the most remarkable finding of this study is that loblolly and slash pine grew in volume at almost identical rates from age 23 to 38 if allowance was made for initial differences in average diameter and for variation in residual basal areas. The slash component of the stand had a smaller initial average diameter than loblolly, and therefore contributed less actual growth per square foot of residual basal area in all treatments and periods.

Choice between the two species for planting or seeding on this and similar sites seems to depend on relative abilities of the stands to grow in diameter before the first thinning. One study in pure species plantations in Georgia *(1)* showed no difference between loblolly and slash in diameter growth through age 10. If these results apply in Louisiana, and they probably do, loblolly and slash pine appear about equally well suited for short rotation management on good Coastal Plain soils in the central and southwest portions of the State.

LITERATURE CITED

1. Jones, E. P., Jr.
   1969. Growth comparison, slash and loblolly pine in Georgia. Forest Farmer 28(5): 10-12.

2. Mesavage, C.
   1947. Tables for estimating cubic-foot volume of timber. USDA Forest Serv. South. Forest Exp. Sta. Occas. Pap. 111, 71 pp.

3. U. S. Department of Agriculture.
   1929. Volume, yield, and stand tables for second-growth southern pines. USDA Misc. Pub. 50, 202 pp.

4. Zahner, R.
   1962. Loblolly pine site curves by soil groups. Forest Sci. 8: 104-110.

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GROWTH COMPONENTS OF MISSISSIPPI FORESTS

Joe F. Christopher

SOUTHERN FOREST EXPERIMENT STATION

Net growth of growing stock in Mississippi amounted to 873.5 million cubic feet in 1966. Of this total, 79 percent was survivor growth, 19 percent was ingrowth and growth on ingrowth, and 2 percent was growth on timber cut during the year.

This report identifies the components of timber growth determined by the fourth survey of Mississippi's forest resources. The information provides answers to such questions as: In which geographic area does the greatest increase occur? What is the net growth of desirable timber species? In what stand component is most of the growth occurring? What net growth percentage can forest managers and resource planners expect from Mississippi forests?

The data are from more than 5,000 permanent sample plots distributed throughout the State in a grid pattern. The plots were installed and measured in 1957 and remeasured in 1967. Growth estimates presented here are for calendar year 1966.

The components of gross annual growth are defined by the Forest Survey as: (1) survivor growth—the increment in net volume of trees in the growing stock at the beginning of the specified year and surviving to its end; (2) ingrowth—the net volume of trees at the time they grew into growing stock during a specified year; (3) growth on ingrowth—the increment in net volume of trees after they grew into growing stock in a specified year; (4) growth on removals—the increment in net volume of growing-stock trees that were cut during the year; (5) mortality—the net volume in growing-stock trees that died during the year.

Net annual growth is gross growth minus mortality.

As shown by table 1, gross growth totaled 945.6 million cubic feet. Survivor growth made up 73 percent of this amount and ingrowth contributed 16 percent. Growth on ingrowth and on trees cut during the year added another 3 percent. The volume of trees that died amounted to 8 percent of the gross growth, or 72.1 million cubic feet. The subtraction of this mortality volume reveals a total net growth of 873.5 million cubic feet.

The Central and South survey regions (fig. 1) contributed the most net growth; together they accounted for 53 percent of the State total.

Table 1.—*Growth components of growing stock by species group and Survey region in Mississippi, 1966*

Survey region	Species group	Growth components					Total	
		Survivor growth	Ingrowth	Growth on ingrowth	Growth on removals	Mortality	Gross growth	Net growth
		Million cubic feet						
Delta	Softwood	3.3	0.6	0.2	0.1	0.4	4.6	4.2
	Hardwood	53.2	10.4	.6	2.2	7.9	74.3	66.4
	Total	56.5	11.0	.8	2.3	8.3	78.9	70.6
North	Softwood	58.9	17.1	3.4	1.1	1.6	82.1	80.5
	Hardwood	72.2	22.4	1.8	1.5	9.3	107.2	97.9
	Total	131.1	39.5	5.2	2.6	10.9	189.3	178.4
Central	Softwood	138.7	30.3	3.3	3.7	5.0	181.0	176.0
	Hardwood	65.2	16.3	1.5	1.1	12.0	96.1	84.1
	Total	203.9	46.6	4.8	4.8	17.0	277.1	260.1
South	Softwood	130.2	20.4	1.5	3.5	7.3	162.9	155.6
	Hardwood	35.5	8.5	.8	.7	10.9	56.4	45.5
	Total	165.7	28.9	2.3	4.2	18.2	219.3	201.1
Southwest	Softwood	86.5	17.3	1.9	1.8	7.2	114.7	107.5
	Hardwood	43.6	10.5	.8	.9	10.5	66.3	55.8
	Total	130.1	27.8	2.7	2.7	17.7	181.0	163.3
All regions	Softwood	417.6	85.7	10.3	10.2	21.5	545.3	523.8
	Hardwood	269.7	68.1	5.5	6.4	50.6	400.3	349.7
	Total	687.3	153.8	15.8	16.6	72.1	945.6	873.5

Timber stands in the North and Southwest made up two-fifths of the net growth. Less than one-twelfth was added by the Delta region.

In table 2 net volume growth is expressed as a percentage of the inventory volume of growing stock. Growth percents decrease as growing stock approaches the carrying capacity of the site. For example, the statewide growth percents were lower in 1966 than a decade ago, but the volume of net growth is higher than previously.

Table 2.—*Net growth percent of growing stock by Survey region, 1966*

Survey region	Softwood	Hardwood
	Percent	
Delta	6.1	5.8
North	9.2	5.9
Central	8.7	5.5
South	7.1	4.2
Southwest	7.7	5.2
All regions	8.0	5.4

This report does not take into consideration the 290 million cubic feet of growing stock destroyed by Hurricane Camille in August 1969. Nearly four-fifths of this volume was in Hancock, Harrison, Jackson, Lamar, and Pearl River Counties. Thus, growth components affected by the disaster are limited principally to the five-county area. The most obvious effect will be an increase in growth percent accompanied by a decline in net growth per acre.

Table 3 presents the major growth components for the State's most important species groups. An outstanding fact is that loblolly pine alone accounts for one-third of the net cubic-foot growth. Loblolly and shortleaf pine together make up about half of the growing stock increment. Another aspect, not so favorable, is the small proportion of hardwood growth occurring in the more desirable species. For example, select oaks provide only one-fourth of the total oak growth, but they make up 30 percent of the oak growing stock volume. Moreover, the gums are producing only 20 per-

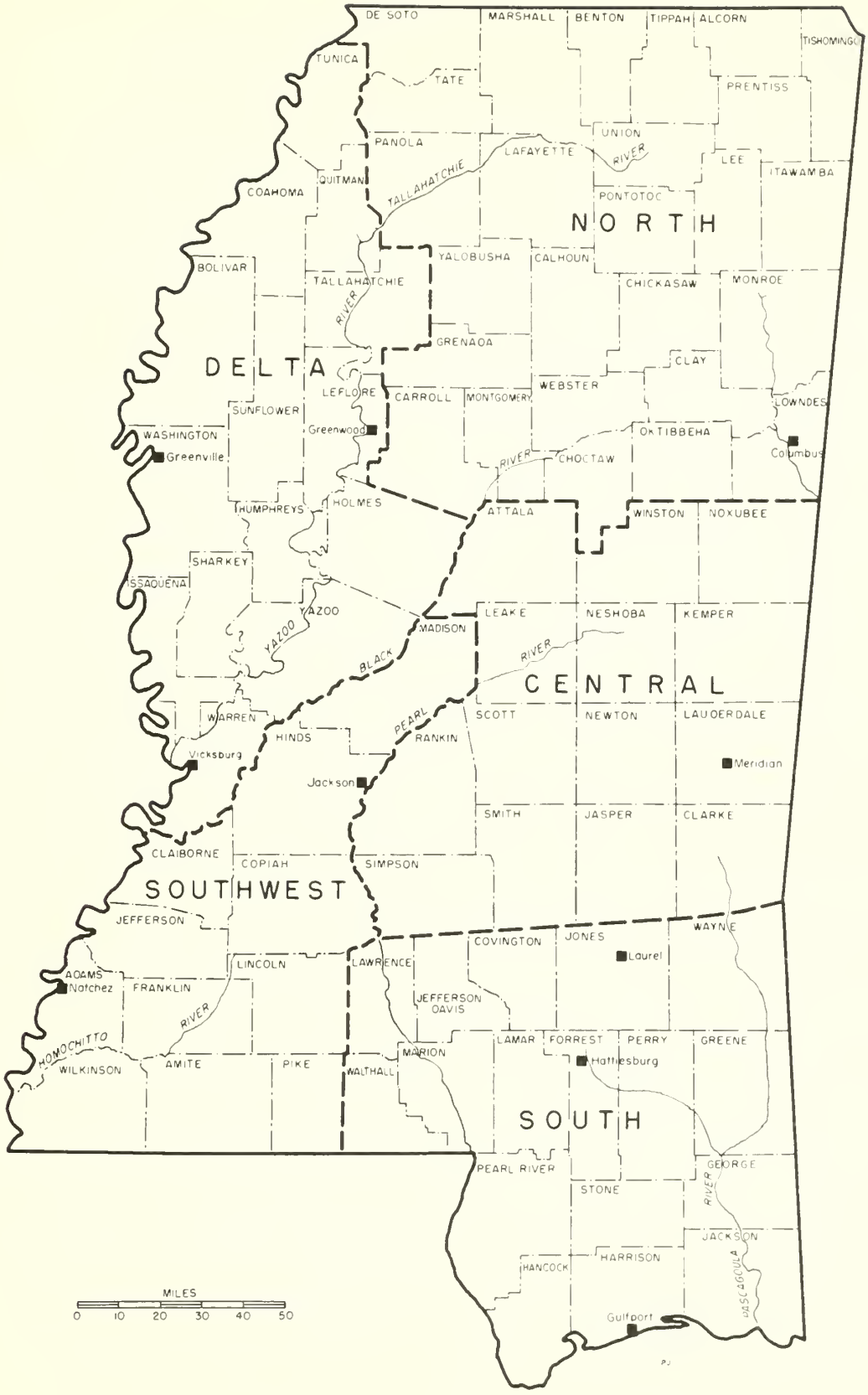

Figure 1.—*Forest Survey regions in Mississippi.*

Table 3.—*Net growth components of growing stock on commercial forest land for selected species, 1966*

Species	Net annual growth	Survivor growth	Ingrowth	Growth on ingrowth	Growth on removals
	Thousand cubic feet				
Pine:					
Loblolly	289,685	233,570	47,930	3,190	4,995
Longleaf	41,670	36,660	3,610	10	1,390
Shortleaf	140,700	105,790	26,110	6,040	2,760
Slash	36,770	28,830	6,590	600	750
Spruce	6,475	5,620	480	120	255
Total	515,300	410,470	84,720	9,960	10,150
Oak:					
Select white	24,075	19,790	3,540	370	375
Select red	18,325	14,610	3,140	350	225
Other white	23,380	16,740	5,360	610	670
Other red	102,420	77,400	21,200	2,370	1,450
Total	168,200	128,540	33,240	3,700	2,720
Gum:					
Sweetgum	53,300	38,750	12,590	660	1,300
Tupelo and blackgum	16,900	14,930	1,400	100	470
Total	70,200	53,680	13,990	760	1,770
Hickory:					
Pecan	6,740	5,270	1,310	90	70
Other hickories	15,460	13,080	1,800	120	460
Total	22,200	18,350	3,110	210	530
Yellow-poplar	10,600	9,170	1,260	70	100

cent of the hardwood growth, though they comprise 25 percent of the total hardwood growing stock volume.

While there are wide variations in growth per acre, the average for the State as a whole was 52 cubic feet. Even better growth is imminent, because the size of the average tree and the number of trees per acre have been increasing.

Detailed information on timber volume and growth in Mississippi is available in recent publications of the Southern Forest Experiment Station. A statewide analysis is presented in "Forest Resources of Mississippi," Resource Bulletin SO-17. Estimates of growth, volume, and acreage in individual counties are tabulated in "Forest Statistics for Mississippi Counties," Resource Bulletin SO-15. Information on timber destroyed by the 1969 storm is summarized in "Timber Damaged by Hurricane Camille in Mississippi," Research Note SO-96.

SOUTHERN FOREST EXPERIMENT STATION

1970

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SO-101

Forest Service, U.S. Dept. of Agriculture

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FIELD GERMINATION OF NUTTALL OAK ACORNS

R. L. Johnson [1]

SOUTHERN FOREST EXPERIMENT STATION

*In newly cleared plots on Sharkey clay near Stoneville, Mississippi, germination was as high as 79 percent for Nuttall oak (*Quercus nuttallii *Palmer) acorns sown unstratified in January and 86 percent for those stratified and sown in April. Most seedlings appeared in June and July, when soil temperatures were usually between 80° and 90° F. Germination was faster and more complete among acorns sown 1 and 2 inches deep than among those sown 4 inches deep. Rodents, mainly chipmunks, dug up and ate some acorns at all three depths.*

A recent nursery study [2] showed that Nuttall oak (*Quercus nuttallii* Palmer) acorns germinate and establish seedlings very well when sown 1 inch below the surface of soil that is covered with litter and partially shaded. Reported here are results of fields tests of this and other combinations of conditions. The tests indicate that rodents are the only major barrier to successful direct-seeding of Nuttall oak in many areas.

[1] The author is Silviculturist at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Mississippi, by the Southern Forest Experiment Station, USDA Forest Service, in cooperation with the Mississippi Agricultural Experiment Station and the Southern Hardwood Forest Research Group.

[2] Johnson, R. L. Improving germination of Nuttall oak acorns. USDA Forest Serv. Res. Note SO-66, 3 pp. South. Forest Exp. Sta., New Orleans, La. 1967.

METHODS

Acorns from three trees near Stoneville, Mississippi, were collected in November 1967 and immediately placed in a walk-in cooler where relative humidity was about 90 percent and temperatures ranged from 35° to 40° F. One week after collection, 50 from each tree were cut and examined; 95 percent were sound, free of insects, and apparently viable.

Nuts from the three trees were mixed in January 1968 and about half the composite was sown in the field. The rest were kept in dry, cold storage in open wooden baskets until February 2. They were then stratified at 35° to 40° F. for 3 months in cloth bags between layers of moist sphagnum and sand. Stratified acorns were sown between April 24 and 30.

In October 1967, all trees 1 inch d.b.h. and larger were cut and removed from 12 strips on a low Sharkey clay flat. Litter was not removed and was only slightly disturbed during cutting and clearing. Strips ran either east-west or north-south and were either 20 or

40 by 90 feet. Widths and directions were replicated three times. Each replication was divided into six 15-foot subplots along the 90-foot side. Each subplot was randomly assigned a combination of one of the two sowing dates and one of three sowing depths, 1, 2, or 4 inches below the soil surface.

There were 10 seed spots in the 15- by 20-foot subplots and 20 in the 15- by 40-foot subplots. Five acorns were sown at each spot.

The effects of pericarp removal were determined on additional sample seed spots representing each of the 24 combinations of environment, stratification treatment, and sowing depth. These seed spots contained both intact and depericarped acorns. One seed spot of each combination was dug up monthly through July. Half the ungerminated acorns were weighed and ovendried at 105° C. for 24 hours to determine moisture content; the other half were put into petri dishes in laboratory germinators at 80° F.

In January 1968, a three-pronged mercury-in-steel distance thermograph was installed near the center of one 40-foot-wide strip which was oriented east and west. Soil temperatures at 1, 2, and 4 inches were recorded continuously through August. Moisture in approximately the surface 3 inches of soil was measured from May to July with a combination surface moisture-density gage. Daily readings and monthly averages for air temperature and rainfall were taken from records kept by the Stoneville weather station, which is about 2 miles south of the study plots.

Weekly from May through mid-July and then every 2 or 3 weeks through September, seedlings appearing above the soil surface were counted at each seed spot. The percentage of acorns that produced seedlings is called germination throughout this note. Final counts were obtained in early October.

RESULTS

As in earlier studies,[3,4] rodent depredation was a major deterrent to successful oak seeding. Since most plots were flooded until late spring, rodent activity was not apparent until May or June. Evidence of digging became pronounced in July. Even acorns at the 4-inch depth were taken. Damage was greater in, though not restricted to, rows adjacent to the woods. In some subplots, almost every seed spot was disturbed. It was not possible to determine the amount of pilferage without terminating the main tests, but it was apparent that plots in which germination was very low were hard hit by rodents. Data from 13 of the 24 treatment combinations were believed to be influenced greatly by pilferage (table 1).

A trap baited with surface-sown Nuttall acorns was set in an area of heavy pilferage in July. A fox squirrel was captured 2 days later. Then a trap was baited with acorns sown 4 inches deep. On two occasions, a chipmunk and a wood rat were captured together. The same two animals were not captured twice; the first pair was still being held when the second pair was caught. Observation of the animals in captivity indicated that only the chipmunk was digging.

Acorns removed from supplementary seed spots did not differ in moisture content or germinability by sowing depths. But the average moisture content of depericarped acorns was 6 percentage points higher in March and April and 20 points higher in May than that of intact acorns. Whole acorns dug up in March and April germinated in the laboratory in from 2 to 6 weeks; those removed in May germinated in 1 to 4 weeks. Depericarped acorns germinated within a week, regardless of when they were removed. Acorns dug up in June and July had either germinated or were rotten.

Over 90 percent of the germination on plots occurred in May, June, and July. Environmental conditions during these months are therefore important.

During May, daily air temperature averaged 71.4° F., or near normal. Average soil temperature was 68° F. 4 inches below the surface and 85° F. at the 1-inch depth (fig. 1). Rain fell 12 different times. Total rainfall was 5.31 inches, 1.10 inches above normal. Soil moisture was always above 50 percent by volume in all plots. The wilting point on Sharkey clay is usually near 30 percent. On May 22, three acorns sown 1 inch deep in January germinated. No further germination was noted in May.

[3] Mignery, A. L. Oak direct seeding in Tennessee. USDA Forest Serv. South. Forest Exp. Sta. South. Forest. Notes 137. 1962.

[4] Sluder, E R. Direct seeding scarlet oak in the North Carolina mountains. USDA Forest Serv. Res. Note SE-41, 2 pp. Southeast. Forest Exp. Sta., Asheville, N. C. 1965.

Table 1.—*Proportion of sown acorns that produced seedlings on individual plots, by orientation, month of sowing, and depth in soil*

Month of sowing and depth	Narrow plots				Wide plots			
	1	2	3	Average	1	2	3	Average
	Percent [1]				*Percent* [2]			
EAST-WEST								
January								
1 inch	90	84	42	72	76	70	76	74
2 inches	18	84	68	57	79	13	10	34
4 inches	92	42	50	61	41	16	14	24
April								
1 inch	80	84	0	55	83	82	92	86
2 inches	22	76	0	33	77	74	0	50
4 inches	4	40	0	15	58	57	0	38
NORTH-SOUTH								
January								
1 inch	78	74	84	79	0	0	53	18
2 inches	52	76	78	69	74	0	57	44
4 inches	44	56	34	45	32	0	46	26
April								
1 inch	72	74	78	75	86	90	52	76
2 inches	62	72	94	76	75	83	68	75
4 inches	50	52	90	64	35	60	39	45

[1] Based on 50 seeds per plot.

[2] Based on 100 seeds per plot.

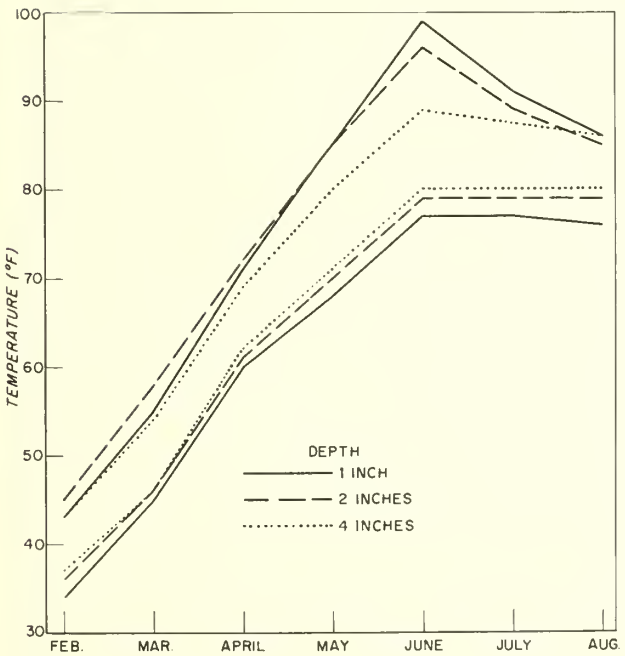

Figure 1.—*Average daily high and low temperatures, by months, at depths of 1, 2, and 4 inches in the soil.*

The temperature in June was 1.9° above normal, and rainfall was 1.57 inches less than normal. Soil temperature stayed above 70° F. at all three depths. This temperature is probably near the minimum for rapid germination. Temperature soared briefly to 114° F. at the 1-inch depth. At the 4-inch depth it was usually between 80° and 90° F. Between May 27 and June 19 there was no rain and surface soil moisture ranged from 30 to 50 percent. Nearly 1/5 of the total germination recorded at the 1-inch depth occurred during this period. A 1.56-inch rain, more than half the 2.30 inches recorded for June, fell on June 20. The rain seemed to stimulate germination or, more likely, growth of the epicotyl. By June 30 germination was about 50 percent complete for acorns 1 inch deep (fig. 2).

July was cooler and wetter than June. Air temperature was 1.1° below normal; rainfall was 5.57 inches, or 1.54 inches above normal. Soil temperature was usually between 80° and 90° F. at all three depths. Over an inch of rain fell on each of three dates, the 3rd, 9th, and 20th, and soil moisture throughout July was above 40 percent. By the end of July, germination was at least 90 percent complete at all depths.

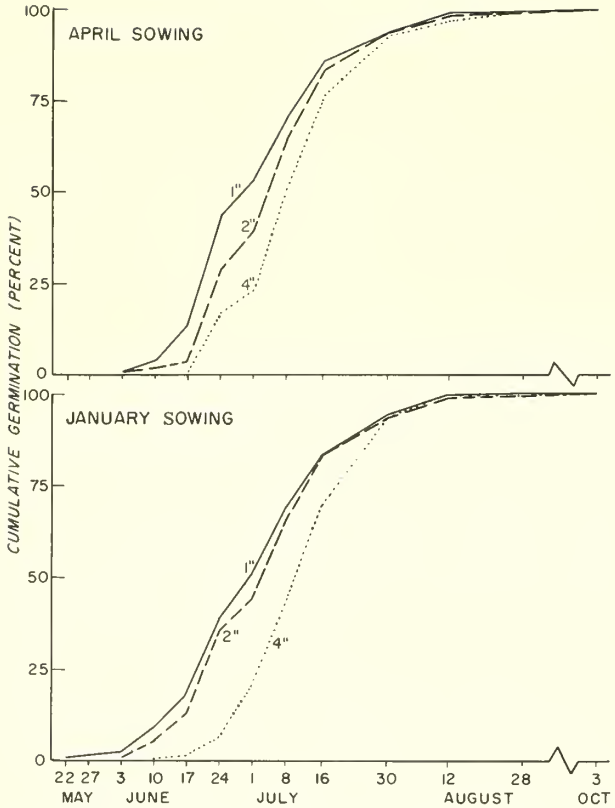

Figure 2.—*Cumulative percents of total germination for acorns sown in spring (above) and winter (below), by measurement date and sowing depth.*

No new seedlings appeared after mid-August. Rains on August 13, 14, and 16 totaled 2.41 inches. Low mortality of germinated seedlings —about 5 percent—is probably attributable to these rains.

A few seedlings died back to ground level and resprouted during the growing season. An occasional one died back and resprouted two or three times. Most seedlings were 8 to 12 inches tall in October.

DISCUSSION

The Sharkey clay flat on which the study was done is typical of the areas where Nuttall oak abounds. The results indicate that direct-seeding of the species is feasible on such areas. Eight of the 24 treatment combinations resulted in germination percents of 70 or more. Severe rodent damage in the plots prevents reliable conclusions about season of sowing or size and orientation of opening. Differences due to these factors did not appear to be great, however.

Three significant conclusions about environment are possible. First, acorns can tolerate standing water from January into May and at least 2 weeks of 30- to 40-percent soil moisture during the germination period. Second, acorns sown 4 inches deep produce acceptable seedlings, but germination is faster and more complete for acorns sown 1 or 2 inches deep. Third, acorns will usually germinate from late May to late July, whether they are sown unstratified in January or stratified and sown in late April.

Although the amount of damage done by rodents was not accurately determined, it is clear that pilferage, particularly by chipmunks, can be a major problem in direct-seeding Nuttall oak. In the study, these animals dug up acorns buried 4 inches beneath the surface. Losses appeared to be greatest near the edges of the cleared strips. If the animals are reluctant to venture far into clearings, an increase in strip length and width may reduce pilferage.

SOUTHERN FOREST EXPERIMENT STATION

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VOLUME TABLES FOR YOUNG LOBLOLLY, SLASH, AND LONGLEAF PINES IN PLANTATIONS IN SOUTH MISSISSIPPI

Dan Schmitt and Dave Bower [1]

SOUTHERN FOREST EXPERIMENT STATION

Data in 7-year-old plantations are the basis for tables of total cubic-foot volume, inside bark, for loblolly, slash, and longleaf pines ranging from 1 to 8 inches in diameter.

Geneticists, ecologists, and forest managers frequently need accurate volume estimates for small trees. As Evert *(1)* pointed out, downward extrapolation of formula tables beyond the basic data often yields highly erroneous results. Volume tables with error estimates exist for small loblolly and slash pines in southern upland areas *(3, 4, 5)*, but apparently are lacking for plantation trees of those two species on the Coastal Plain. None exist for small longleaf pines.

This report includes tables for cubic-foot volume (inside bark) of loblolly, slash, and longleaf, the three most important pines on the southern Coastal Plain.

[1] The authors are Plant Geneticist stationed in Gulfport and Mathematical Statistician stationed in New Orleans, Southern Forest Experiment Station, USDA Forest Service, at the time research was initiated. Bower is now Forest Biometrician at the Weyerhaeuser Research Center, Centralia, Washington.

METHODS

Two hundred sample trees in south Mississippi were removed at random from each of three large plantations. Trees on the plantations were spaced at 10 feet by 10 feet and were 7 years old when they were cut. They were removed at ground level and diameter and bark thickness were measured at ground level, 3 feet, 4.5 feet, and (total height +4.5 feet)/2. Diameters were measured to the nearest 1/10 inch and height to the nearest 1/10 foot. Total cubic-foot volume (inside bark) for each sample tree was computed by summing the volumes of each conic section and adding the volume of the terminal cone. Volumes were computed to five decimal places and rounded to three.

Weighted and unweighted least-squares solutions of the combined variable formula $V = a + b\ D^2H$, were computed for each species. Weighting substantially reduced the residual sum of squares, according to Furnival's index *(2)*, which permits direct comparison of weighted and unweighted regressions by retransform-

ing residuals. Weights yielding the most efficient estimates were $1/(D^2H)^2$ for slash and loblolly and $1/D^2H$ for longleaf. The ratio of the standard error of the unweighted expression to the standard error of the best weighted expression (retransformed) was 1.18 for slash, 1.49 for loblolly, and 1.84 for longleaf pine. Covariance analysis showed that the regression coefficients for the three species differed significantly; consequently, no attempt was made to provide a combined table for all species.

The combined-variable equation of best fit for each species is:

Species	Equation	Transformed standard error
Slash	$V = 0.02408 + 0.0021058\ (D^2H)$	0.10633
Loblolly	$V = 0.03789 + 0.0020911\ (D^2H)$	0.10693
Longleaf	$V = 0.02855 + 0.0020404\ (D^2H)$	0.03192

Tables 1, 2, and 3, which show total cubic-foot volume for 1-inch diameter and 1-foot height classes for the three species, were constructed on the basis of these formulas. We do not recommend extrapolation beyond the limits of the tables.

LITERATURE CITED

1. Evert, F.
   1969. Use of form factor in tree-volume estimation. J. Forest. 67: 126-128.
2. Furnival, G. M.
   1961. An index for comparing equations used in constructing volume tables. Forest Sci. 7: 337-341.
3. Goebel, N. B., and Warner, J. R.
   1962. Volume tables for small diameter loblolly, shortleaf and Virginia pine in the Upper South Carolina Piedmont. S. C. Agr. Exp. Sta. Forest Res. Ser. 7, 7 pp.
4. Perry, T. O., and Roberts, A. Y.
   1964. Volume formulas for loblolly pine seedlings in the vicinity of Raleigh, North Carolina. J. Forest. 62: 186-187.
5. Potts, S. M.
   1952. Volume tables for small-diameter loblolly and shortleaf pine trees. Tenn. Val. Authority Tech. Note 10, 23 pp.

Table 2.—*Young loblolly pine cubic-foot volume (insid*

D.b.h., o.b. (inches)	7	8	9	10	11	12	13	14
1	0.053	0.055	0.057	0.059	0.061	0.063	0.065	0.06
2	.097	.105	.113	.122	.130	1.38	.147	.15
3	.170	.189	.207	.226	.245	.264	.283	.30
4			.339	.373	.406	.439	.473	.50
5					.613	.665	.718	.77
6								
7								
8								

[1] Standard error of estimate = 0.000197 cubic feet/D^2H

Table 1.—*Young slash pine cubic-foot volume (inside bark)* [1]

D.b.h., o.b. (inches)	Total height in feet																													
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
1	0.041	0.043	0.045	0.047	0.049	0.051	0.053	0.056																						
2	.091	.100	.108	.117	.125	.134	.142	.150	0.159	0.167	0.176	0.184	0.192	0.201																
3	.176	.195	.214	.232	.251	.270	.289	.308	.327	.346	.365	.384	.403	.422	0.441	0.460	0.479	0.498	0.517	0.536	0.555	0.574								
4	.294	.327	.361	.395	.428	.462	.496	.529	.563	.597	.630	.664	.698	.732	.765	.799	.833	.866	.900	.934	.967	1.001	1.035	1.068	1.102	1.136				
5	.445	.498	.550	.603	.656	.708	.761	.814	.866	.919	.972	1.024	1.077	1.130	1.182	1.235	1.287	1.340	1.393	1.445	1.498	1.551	1.603	1.656	1.709	1.761	1.814	1.867	1.919	1.972
6				.858	.934	1.010	1.085	1.161	1.237	1.313	1.389	1.464	1.540	1.616	1.692	1.768	1.843	1.919	1.995	2.071	2.147	2.222	2.298	2.374	2.450	2.526	2.601	2.677	2.753	2.829
7								1.572	1.675	1.778	1.881	1.984	2.088	2.191	2.294	2.397	2.500	2.604	2.707	2.810	2.913	3.016	3.120	3.223	3.326	3.429	3.532	3.635	3.739	3.842
8										2.315	2.450	2.585	2.719	2.854	2.989	3.124	3.259	3.393	3.528	3.663	3.798	3.932	4.067	4.202	4.337	4.471	4.606	4.741	4.876	5.011

[1] Standard error of estimate = 0.000225 cubic feet/D^2H.

D.b.h., o.b. (inches)	Total height in feet																													
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1	0.071	0.074																												
2	.172	.180	0.189	0.197	0.205	0.214	0.222	0.230	0.239																					
3	.339	.358	.377	.396	.414	.433	.452	.471	.490	0.508	0.527	0.546	0.565	0.584	0.603	0.621	0.640													
4	.573	.607	.640	.674	.707	.741	.774	.808	.841	.874	.908	.941	.975	1.008	1.042	1.075	1.109	1.142	1.176	1.209	1.242	1.276	1.309	1.343						
5	.874	.927	.979	1.031	1.084	1.136	1.188	1.240	1.293	1.345	1.397	1.449	1.502	1.554	1.606	1.659	1.711	1.763	1.815	1.868	1.920	1.972	2.025	2.077	2.129	2.181	2.234	2.286		
6	1.242	1.318	1.393	1.468	1.544	1.619	1.694	1.769	1.845	1.920	1.995	2.071	2.146	2.221	2.296	2.372	2.447	2.522	2.598	2.673	2.748	2.823	2.899	2.974	3.049	3.124	3.200	3.275	3.350	
7		1.780	1.882	1.985	2.087	2.190	2.292	2.395	2.497	2.600	2.702	2.805	2.907	3.009	3.112	3.214	3.317	3.419	3.522	3.624	3.727	3.829	3.932	4.034	4.137	4.239	4.341	4.444	4.546	4.649
8				2.581	2.715	2.848	2.982	3.116	3.250	3.384	3.518	3.651	3.785	3.919	4.053	4.187	4.321	4.454	4.588	4.722	4.856	4.990	5.124	5.257	5.391	5.525	5.659	5.793	5.927	6.060

Table 3.—*Young longleaf pine cubic-foot volume (inside bark)*[1]

D.b.h., o.b. (inches)	Total height in feet																												
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1	0.039	0.041	0.043	0.045	0.047	0.049	0.051	0.053	0.056	0.058	0.060	0.062	0.064																
2	.070	.078	.086	.094	.102	.111	.119	.127	.135	.143	.151	.160	.168	0.176	0.184	0.192	0.200												
3	.121	.139	.158	.176	.194	.213	.231	.249	.268	.286	.304	.323	.341	.360	.378	.396	.415	0.433	0.451	0.470	0.488	0.506	0.525						
4	.192	.225	.258	.290	.323	.355	.388	.421	.453	.486	.519	.551	.584	.617	.649	.682	.715	.747	.780	.813	.845	.878	.910	0.943	0.976	1.008	1.041	1.074	1.106
5					.488	.539	.590	.641	.692	.743	.794	.845	.896	.947	.998	1.049	1.100	1.151	1.202	1.253	1.304	1.355	1.406	1.457	1.508	1.559	1.610	1.661	1.712
6									.984	1.057	1.131	1.204	1.278	1.351	1.425	1.498	1.572	1.645	1.718	1.792	1.865	1.939	2.012	2.086	2.159	2.233	2.306	2.380	2.453
7													1.729	1.829	1.929	2.029	2.129	2.229	2.329	2.429	2.528	2.628	2.728	2.828	2.928	3.028	3.128	3.228	3.328
8															2.510	2.641	2.771	2.902	3.032	3.163	3.294	3.424	3.555	3.685	3.816	3.947	4.077	4.208	4.338

[1] Standard error of estimate = 0.00375 cubic feet/$(\sqrt{D^2H})$.

SOUTHERN FOREST EXPERIMENT STATION

1970

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SPECIFIC GRAVITY AND FIBER LENGTH OF LOBLOLLY AND SPRUCE PINES ON THE SAME SITE

E. B. Snyder and J. M. Hamaker [1]

SOUTHERN FOREST EXPERIMENT STATION

Among trees growing sympatrically in southern Mississippi, the average specific gravity of the outer wood was 0.46 for spruce pine and 0.54 for loblolly—a significant difference. Mean fiber length did not differ significantly between species. The small fiber variation among spruce pine trees indicates difficulty in selecting for genetic fiber-length differences in this species.

In the study reported here, fiber length, summerwood percent, and specific gravity of spruce pine *(Pinus glabra* Walt.) were compared with those of loblolly *(P. taeda* L.) pine growing in the same stands. The trees were in south Mississippi, on moist sites that appeared suitable for either species. It was thus possible to compare wood properties without the confounding effects of site. The variation in wood-property characters of loblolly pine has been reasonably well defined, and we were interested in learning whether variation within spruce pine differed sufficiently to require a separate breeding approach.

[1] The authors are Principal Plant Geneticist and Biological Laboratory Technician, respectively, at the Institute of Forest Genetics, Gulfport, Miss.

METHODS

The three characters studied were determined on increment cores from paired trees of the two species. Five stands were located within a 25-mile radius, and in each stand two trees of each species were selected so that a spruce pine was paired with a loblolly of approximately equal size. Diameter at breast height averaged 16.3 inches for the 10 spruce pines and 16.5 inches for the 10 loblolly pines. Both averaged 52 rings. The approximate range in ring number for each species was from 40 to 70.

From each tree two increment cores 11 mm. in diameter were removed at breast height. On each core the rings were counted and the total length measured to the nearest millimeter. Specific gravities and summerwood percentages were determined on the outer 51 mm. *(2, 3)*. The summerwood percentage was the average of two readings from opposite sides of each core *(4)*. For this, phloroglucinol-HC1 stain was used but the data were converted to a methylene blue-malachite green basis *(8)*, since the latter stain has become standard in our laboratory. The outer two summerwood

rings were used to determine the length of 36 fibers per core according to methods of Strickland and Goddard *(6)*.

RESULTS

Mean specific gravity and summerwood percentage of the outerwood of spruce pine, 0.46 and 43 percent, were significantly lower (0.05 level) than in loblolly pine, 0.54 and 55 percent (fig. 1, table 1). Taras and Saucier *(7)* reported a mean whole-core specific gravity of 0.45 from similar-sized spruce pines in counties adjacent to those we sampled.

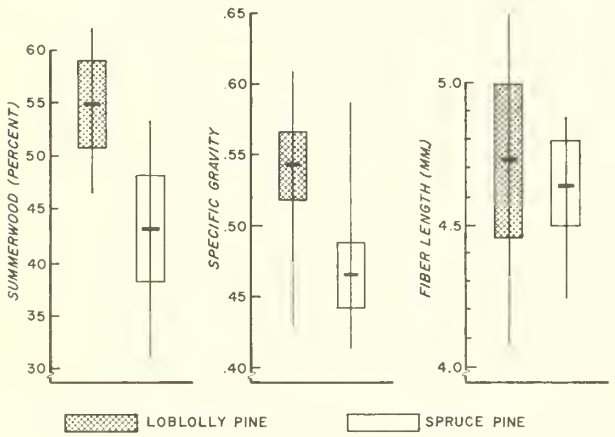

Figure 1.—*Means (crossbars), 5-percent confidence intervals (rectangles), and ranges (vertical lines) of 10 loblolly and 10 spruce pines.*

Table 1.—*Analyses of variance and components of variance for specific gravity and summerwood percentage of the species combined*

Source of variation	Degrees of freedom	Mean square	Components of variance	
			Units [2]	Percent
SPECIFIC GRAVITY				
Species	1	0.07268*	0.0036	29
Stands	4	.00112	.0000	0
Species × stands	4	.00805	.0000	0
Trees/stand	10	.00534	.0000	0
Cores/tree	20	.00884	.0090	71
SUMMERWOOD PERCENTAGE				
Species	1	1398.306*	63.9	56
Stands	4	11.536	.0	0
Species × stands	4	119.620	4.1	3
Trees/stand	10	86.542*	37.5	30
Cores/tree	20	12.165	12.2	10

* Significant at the 0.05 level.

Figure 2 graphs the relation between specific gravity and percentage of summerwood. The regressions for the two species may differ, but this point is not statistically demonstrable.

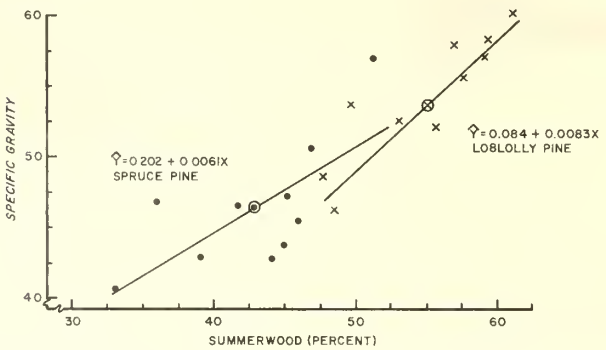

Figure 2.—*Regressions of specific gravity on summerwood percentage. Circled points are means.*

Mean fiber lengths, 4.6 mm. for spruce pine and 4.7 mm. for loblolly, were not significantly different (fig. 1, table 2). Solution of a two-stage sampling formula *(5)* gave the average standard error as 3.4 percent of the mean, which indicates good sampling precision from the 36 fibers per core. Burley et al. *(1)* found that 40 to 50 fibers were enough for their intra-tree research. The mean square for spruce pines within stands was not homogeneous with that

Table 2.—*Analyses of variance and components of variance of fiber lengths*

Source of variation	Degrees of freedom	Mean square	Components of variance	
			Mm.[2]	Percent
LOBLOLLY PINE				
Stands	4	16.161	0.079	15
Trees/stand	5	4.851	.034	6
Cores/tree	10	2.438*	.057	10
Fibers/core	700	.374	.374	69
SPRUCE PINE				
Stands	4	6.835*	.039	8
Trees/stand	5	.570	.000	0
Cores/tree	10	1.164*	.022	5
Fibers/core	700	.367	.367	87
COMBINED ANALYSIS [1]				
Cores/tree	20	1.801*	.040	. . .
Fibers/core	700	.370	.370	. . .

[1] Mean squares for trees are not homogeneous. Therefore these two terms are the only ones that can be combined.

* Significant at the 0.05 level.

for loblolly pine. The variances were 0.6 and 4.7—a significant difference. The value for spruce pine is low because trees of each pair frequently were almost identical in average fiber length. Possibly spruce pine is more inbred than loblolly.

In summary, the specific gravity of spruce pine outer wood was 15 percent lower than that of loblolly. There was no significant difference between species in fiber length, but within sampling areas spruce pines varied little in this character. Selecting for fiber length would thus appear to be more difficult in spruce pine than in loblolly pine.

LITERATURE CITED

1. Burley, J., Burrows, P. M., Pattinson, J. V., and Press, A.
   1967. Tracheid length measurement techniques for small wood samples. Rhodesia Zambia Malawi J. Agr. Res. 5: 289-296.

2. Echols, R. M.
   1959. Estimation of pulp yield and quality of living trees from paired-core samples. TAPPI 42: 875-877.

3. Echols, R. M.
   1960. Effects of growing space on wood specific gravity in loblolly pine. Soc. Amer. Forest. Proc. 1959: 140-143.

4. Echols, R. M., and Bowden, A. B.
   1961. Inexpensive ring analyzer for cumulative summerwood measurements. Forest Sci. 7: 147-148.

5. Snedecor, G. W., and Cochran, W. G.
   1967. Statistical methods. Ed. 6, 593 pp. Ames: Iowa State Univ. Press.

6. Strickland, R. K., and Goddard, R. E.
   1966. Correlation studies of slash pine tracheid length. Forest Sci. 12: 54-62.

7. Taras, M. A., and Saucier, J. R.
   1968. Wood density surveys of the minor species of yellow pine in the Eastern United States. I. Spruce pine *(Pinus glabra* Walt.). USDA Forest Serv. Res. Pap. SE-34, 15 pp. Southeast. Forest Exp. Sta., Asheville, N. C.

8. Wiksten, A.
   1945. [A method of measuring springwood and summerwood in the annual ring.] Medd. Statens Skogsförsöksanstalt 34: 451-496.

SOUTHERN FOREST EXPERIMENT STATION

Forest Service, U. S. Dept. of Agriculture

1970

U.S. FOREST SERVICE RESEARCH NOTE

SO-104

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PRESCRIBED WINTER FIRE THINS DENSE LONGLEAF SEEDLING STAND

William R. Maple [1]

SOUTHERN FOREST EXPERIMENT STATION

A prescribed winter fire in central Alabama thinned a longleaf pine stand from 177,000 seedlings per acre to 6,300. Seedlings with exposed root collars were about twice as susceptible to the fire as seedlings whose root collars were at or near the soil surface.

When there is a bumper seed crop, regeneration of longleaf pine *(Pinus palustris* Mill.) may be too successful, particularly if the seedbed has been prepared. Unless the dense seedling stands are thinned, height growth is retarded and brown-spot needle disease (caused by *Scirrhia acicola* (Dearn.) Siggers)[2] becomes epidemic. Since natural thinning is slow in longleaf pine, these conditions persist and regenerated areas may remain out of active production for unnecessarily long periods.

Prescribed burning in winter has been proposed as a cheap method for thinning such stands, and results presented in this note are promising. A winter burn on an area where litter had accumulated for 1 year successfully thinned an extremely dense stand of year-old longleaf pine seedlings in the upper Piedmont of Alabama.[3] More important, it was found that seedlings with exposed root collars are more susceptible to fire than seedlings whose root collars are at the soil surface.

Before fire can be recommended for thinning seedling stands, it must be shown that some seedlings will be killed while an adequate number will survive with little or no injury. Bruce [4] reported that vigorous year-old longleaf seedlings established on a freshly burned area survived a prescribed winter fire in southern Mississippi. He speculated that seeds which germinated while suspended in the litter above mineral soil would be more susceptible to fire because their root collars would be exposed. The influence of root-collar exposure was measured in the present study.

An area that had received a shelterwood regeneration trial in Coosa County, Alabama, was burned just prior to the 1967 seed fall. The seed crop was unusually large, and 177,000 longleaf seedlings were present in July of 1968. A 2-acre study plot was established within the

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[2] Wahlenberg, W. G. Longleaf pine. 429 pp. Pack Forest. Found., Wash., D. C., in cooperation with USDA Forest Serv. 1946.

[3] The author is indebted to Kaul Lumber Company for assistance in this study.

[4] Bruce, D. Fire resistance of longleaf pine seedlings. J. Forest. 49: 739-740. 1951.

regeneration area at the end of the first growing season to determine whether winter burning of the needles that had accumulated in 1 year would safely thin the dense seedling stand. Ten transects were established perpendicular to the slope. Ten sample points were established along each transect at 10-foot intervals. Two vigorous, well-established seedlings of similar size near each point were examined and their position marked for easy relocation. One of the seedlings had an exposed root collar; the other had a root collar at or close to the soil surface. Diameters at the root collar averaged 0.1 inch.

The prescribed fire was set around the perimeter of the study area in early February 1969, 2 days after a moderate rain. During the fire the wind was from the northwest at 5 m.p.h., the relative humidity was about 50 percent, the adjusted fuel moisture was over 15 percent,[5] and the air temperature was 45° F. The fire consumed most of the litter that had accumulated since the previous burn.

Survival percents for the vigorous, paired seedlings in June and December of 1969 were:

Root collar	June	December
Normal	53	35
Exposed	16	15

[5] Nelson, R. M. The national fire danger rating system: derivation of spread index for Eastern and Southern States. USDA Forest Serv. Res. Pap. SE-13, 44 pp. Southeast. Forest Exp. Sta., Asheville, N. C. 1964.

A "t" test comparing survival results indicated that differences were significant at the 0.01 level between normal seedlings and those with an exposed root collar at both measurement dates. Mortality of normal seedlings between measurement dates was significant; that of exposed seedlings was not. The fire probably reduced the vigor of some normal seedlings, which died in periods of high moisture stress during the growing season. In any case, seedlings with exposed root collars were about twice as susceptible to the fire as seedlings with root collars at or near the soil surface.

Since only vigorous seedlings were chosen for measurement of the effects of root-collar exposure, mortality on the study area as a whole was higher than among paired seedlings. The stocking on randomly spaced milacre plots indicates that the burn was highly successful as a thinning treatment. On portions of the regeneration area that were not burned, stocking dropped from 177,000 seedlings per acre in July of 1968 to about 45,000 in December 1969. Far too many seedlings were still present. In contrast, the burned area contained about 6,300 seedlings per acre. A milacre stocking percentage of 85 indicates good seedling distribution. The majority of the survivors on burned plots are vigorous and appear to be brown-spot resistant. They are expected to begin height growth soon after the shelterwood overstory is removed.

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SEEDED LEGUMES REPRODUCE POORLY ON CUTOVER LONGLEAF PINELANDS

Lowell K. Halls, Carroll J. Perkins, and Jim Turk [1]

SOUTHERN FOREST EXPERIMENT STATION

A combination of disking, fertilizing, and seeding was best for establishing partridge-pea, wild sensitive plant, and common lespedeza on cutover longleaf pinelands in southern Alabama. Common lespedeza seedings were most successful and partridge-pea the least. Number of plants and seed pods declined so rapidly after the first year that seeding these legumes to increase the food supply for game birds is probably not practical.

Fruits of herbaceous legumes are vital foods for bobwhite quail *(Colinus virginiana* L.) and eastern wild turkeys *(Meleagris gallopavo* L.) in longleaf pine *(Pinus palustris* Mill.) stands, but growing conditions for legumes are poor under well-stocked timber stands. Game managers have considered seeding openings that are created when trees are harvested in the hope that legumes will maintain themselves until the crowns of the young trees close. Results of the seeding study described here are not encouraging. Satisfactory methods were found for establishing legumes of three species, but the plants do not persist long enough to justify the expense of treatment.

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Perkins is a wildlife biologist at Bainbridge, Georgia, and Turk is a forester at Atmore, Alabama. Both are employees of the International Paper Company.

METHODS

Three treatments, seeding, disking, and fertilizing, were tested singly and in all combinations. The three legume species chosen for the experiment were partridge-pea *(Cassia fasciculata* Michx.), wild sensitive plant *(C. nictitans* L.), and common lespedeza *(Lespedeza striata* (Thunb.) H. & A.). All provide excellent food for game birds, grow well on sandy loam soils such as those on which longleaf pine thrives, and are widely distributed throughout the South.

The study area is near Bay Minette in southern Alabama on longleaf pine forest lands that were clearcut of all commercial timber in 1965. In early March of 1966, four blocks 96 by 144 feet were staked out and tree tops from previously harvested trees were removed. The soil

types were Tifton very fine sandy loam on two blocks, Lakeland loamy fine sand on one, and a Bowie-Lakeland-Cuthbert soil complex on one. Each block was divided into 24 plots 24 feet on a side, and each plot was assigned a species-treatment combination. The treatments consisted of disking, fertilizing, and seeding, singly and in all combinations, plus an untreated control. Single disking was done with a tandem disk drawn by a crawler tractor on March 15-20, 1966. On April 1 fertilizer (0-14-14 analysis) was broadcast on assigned plots at the rate of 300 pounds per acre. Sowing rates for the seeds, which were broadcast unscarified, were 15 pounds per acre for partridge-pea, 8 pounds per acre for wild sensitive plant, and 20 pounds for common lespedeza. Germination tests on filter paper showed partridge-pea germination to be 3 percent and wild sensitive plant 23 percent. Lespedeza seeds were not tested.

In April 1968 the treatments were repeated on plots adjacent to the 1966 seedings. The partridge-pea and wild sensitive plant seeds sown in 1968 were scarified by immersion in hot water (176° F.) for 3 minutes. After immersion, the partridge-pea seeds were placed in a plastic bag, covered with about an inch of water, placed in a refrigerator for 5 days, then seeded. Wild sensitive plant seeds were dried immediately after the hot-water treatment and seeded a few days later. Laboratory tests conducted for 30 days after treatment showed germination to be 99 percent for partridge-pea and 81 percent for wild sensitive plant. Untreated common lespedeza seeds were sown because previous experience showed that scarification was unnecessary for high germination.

Annually in late September or October the number of plants of each seeded species was recorded from four systematically located 3.1- by 3.1-foot quadrats on each plot.

The number of pods was recorded each year except 1967 as an indicator of seed production for partridge-pea (four to 12 seeds per pod) and wild sensitive plant (six to nine seeds per pod). It was not practical to attempt a count of lespedeza seeds.

A split-plot analysis of variance was used to test whether the numbers of plants and seed pods were significantly affected (0.05 level) by treatments.

Monthly rainfall records were taken from the State's fire tower in southern Baldwin County. In 1966 rainfall was above normal and soil moisture was plentiful throughout the year (table 1). Rainfall was also good in 1967, but there was a relatively dry period during the spring. In 1968 rainfall was considerably below average through June but moderate thereafter. In 1969 rainfall was exceptionally heavy through August but light during the fall.

Table 1.—*Monthly rainfall in southern Baldwin County, Alabama, 1966-1969*

Month	1966	1967	1968	1969
	Inches			
January	5.06	5.74	3.08	4.78
February	10.02	7.97	3.22	4.16
March	2.77	.91	1.47	8.90
April	2.91	2.33	2.04	5.34
May	5.41	2.76	3.35	11.39
June	5.92	6.24	2.94	4.69
July	5.74	4.67	5.18	17.46
August	12.94	9.36	4.93	9.00
September	5.08	5.75	1.31	1.32
October	5.74	6.72	3.24	1.84
November	4.85	.73	3.59	1.51
December	3.58	5.59	6.36	6.18
	70.02	58.77	40.71	76.57

PARTRIDGE-PEA

1966 Seedings

In the fall of 1966 the average number of plants per quadrat was less than one and did not differ significantly between treatments (table 2). One half of the seeded plots produced plants, but there were never more than three plants per quadrat. Low seed germination partially accounted for the sparseness of partridge-pea plants.

In 1967 the number of plants per quadrat increased to 10.9 on plots that had been disked, fertilized, and seeded. The increase in plants was probably a result of delayed germination of seeds sown the previous year. The number of plants on disked, fertilized, and seeded plots was significantly greater than the average of 0.4 plant per quadrat for the other treatments.

appeared best, the plants did not persist for more than 2 years after any treatment.

The somewhat variable response of partridge-pea to fertilizer confirms other studies *(3)* which show that fertilizer increases production of partridge-pea at high plant densities but not at low density, and that the responses vary among soil types.

The lack of partridge-pea plants on all but one of the unseeded plots indicates it was very scarce in the uncut timber stand, and explains why it did not respond to soil disturbance as it has in other studies *(5)*.

Seed was the most significant factor influencing the establishment of wild sensitive plant in 1966. In contrast to studies by Cushwa and Jones *(2)*, disking by itself failed to influence legume populations, probably because of seed scarcity. It appears, though, that in combination with seeding and fertilization, disking increases yields of wild sensitive plant. None of the treatments tested seem likely to be of significant benefit for more than 2 or 3 years on unburned forest ranges, and all are likely to fail during drought years.

The relative good stands of common lespedeza obtained in 1966 confirm earlier findings by Halls *et al. (4)* that common lespedeza can be seeded into undisturbed forest soils when moisture is plentiful. In both the 1966 and 1968 tests the combination of disking, fertilizing, and seeding facilitated the establishment and maintenance of common lespedeza, a response also noted by Burton and Mathews *(1)*. Even though the 1968 seedings were less successful than the 1966 seedings, the relationship among treatments was similar in the 2 years.

With currently available techniques it appears impractical to seed partridge-pea, wild sensitive plant, or common lespedeza into newly regenerated pine stands to increase the supply of food for game birds.

LITERATURE CITED

1. Burton, G. W., and Mathews, A. C.
   1949. A study of species, seeding methods and fertilizing practices for use on piney woods ranges. Ga. Coastal Plain Exp. Sta. Tech. Pap. 1, 22 pp.

2. Cushwa, C. T., and Jones, M. B.
   1969. Wildlife food plants on chopped areas in the Piedmont of South Carolina. USDA Forest Serv. Res. Note SE-119, 4 pp. Southeast. Forest Exp. Sta., Asheville, N. C.

3. Foote, L. E., and Jackobs, J. A.
   1966. Response of partridge pea *(Cassia fasciculata* Michx.) and Korean lespedeza *(Lespedeza stipulacea* L.) to differences in soil types, phosphorus fertilization, and plant populations. Agron. J. 58: 419-423.

4. Halls, L. K., Burton, G. W., and Southwell, B. L.
   1957. Some results of seeding and fertilization to improve southern forest range. USDA Forest Serv. Southeast. Forest Exp. Sta., Sta. Pap. 78, 26 pp.

5. Murry, R. E.
   1957. A recently developed forestry planting technique favorable to bobwhite quail. Southeast. Assoc. Game and Fish Comm. 10th Annu. Conf. Proc. 1956: 242-244.

Table 3.—*Treatment effects on number of seed pods produced by partridge-pea and wild sensitive plants* [1]

Species and treatment	Treated in 1966			Treated in 1968	
	1966	1968	1969	1968	1969
	Seed pods per 3.1-ft.-sq. quadrat				
Partridge-pea					
Disk	1.0	0	0	0	0
Fertilize	0	0	0	0	0
Seed	2.2	7.5	.7	6.1	1.1
Disk-fertilize	0	0	1.0	0	.8
Disk-seed	5.5	0	0	32.8	0
Fertilize-seed	23.7	31.0	2.9	7.2	15.2
Disk-fertilize-seed	81.7	82.0	2.4	77.0	0
None	0	0	0	0	0
Wild sensitive plant					
Disk	34.2	3	.2	5.0	0
Fertilize	282.2	.9	1.5	4.4	0
Seed	466.7	1.0	0	15.7	1.0
Disk-fertilize	81.0	0	.3	0	0
Disk-seed	918.7	.6	1.4	.8	0
Fertilize-seed	677.8	2.1	.4	0	1.2
Disk-fertilize-seed	1,330.0	10.4	.6	28.4	.1
None	23.2	.4	0	1.2	.3

[1] The number of seeds per pod ranges from four to 12 for partridge-pea and six to nine for wild sensitive plant.

1968 Seedings

Very few plants were established from this seeding, probably because of dry weather in spring and early summer. Treatments did not significantly influence numbers of plants or pods present in 1968 or 1969.

COMMON LESPEDEZA

1966 Seedings

Seeding produced good stands of common lespedeza (244 plants per quadrat) in 1966, and the seeded stands were significantly improved by disking (512 plants per quadrat) (table 2). Fertilizer improved the seeded stands only when used in combination with disking (705 per quadrat).

The rare occurrence of this species on unseeded plots indicates that it was of little consequence in the study area.

In 1967 the plant numbers on seeded plots were greatly reduced over the previous year, but they were still significantly higher than on unseeded plots. In this year there were more plants on fertilized and seeded plots (115 per quadrat) than on seeded plots that were not fertilized (24 per quadrat).

In 1968 plant numbers were further reduced. The disked, fertilized, and seeded plots were significantly better (68 plants per quadrat) than the seeded and fertilized plots (16 plants per quadrat), which were significantly better than all others (one per quadrat).

By 1969 only the disked, fertilized, and seeded plots supported lespedeza plants (six per quadrat).

1968 Seedings

In 1968 the seeded plots contained significantly more plants than unseeded plots, but by far the best results were obtained from the combination of disking, fertilizing, and seeding (62 plants per quadrat). As a result of the dry spring and summer, the stands were inferior to the first-year stands in 1966. Only the disked, fertilized, and seeded plots contained plant numbers of significance in 1969.

DISCUSSION

The generally unsuccessful seedings of partridge-pea were probably the results of poor germination in 1966 and the extended drought in spring and summer of 1968. Although the combination of disking, seeding, and fertilizing

Table 2.—*Treatment effects on density of legumes*

Species and treatment	Treated in 1966				Treated in 1968	
	1966	1967	1968	1969	1968	1969
	Plants per 3.1-ft.-sq. quadrat					
Partridge-pea						
Disk	0.2	0	0	0	0	0.2
Fertilize	0	.4	0	0	0	0
Seed	.8	0	3.8	2.0	.8	.7
Disk-fertilize	0	0	.1	.2	0	.1
Disk-seed	1.2	1.5	0	0	8.2	0
Fertilize-seed	.5	1.2	3.2	.4	.4	.5
Disk-fertilize-seed	.7	10.9	6.3	.1	13.7	0
None	0	0	0	0	0	0
Common lespedeza						
Disk	.2	.5	.7	0	0	0
Fertilize	0	.4	0	0	0	0
Seed	243.8	13.8	.6	0	3.6	0
Disk-fertilize	0	7.3	.2	0	.6	2.2
Disk-seed	512.0	35.1	3.2	0	11.9	.7
Fertilize-seed	242.0	57.1	16.2	3.2	7.6	.7
Disk-fertilize-seed	705.0	172.4	67.7	5.6	62.3	52.2
None	0	0	0	0	0	0
Wild sensitive plant						
Disk	1.2	4.0	.4	.1	.6	0
Fertilize	2.8	1.8	1.0	.2	1.8	0
Seed	39.5	.8	.3	0	1.4	.2
Disk-fertilize	.8	1.4	.9	0	0	0
Disk-seed	46.0	.2	.2	.1	3.9	0
Fertilize-seed	29.8	5.4	1.0	.2	0	.2
Disk-fertilize-seed	34.2	.3	3.4	.3	4.0	.1
None	2.2	.9	.7	0	1.0	.2

In the third and fourth years after treatment, plant numbers were not significantly higher on treated than on check plots. The number of seed pods was closely correlated with number of plants, and trends were the same for both expressions of treatment success (table 3).

1968 Seedings

These seedings were generally poor, probably because of dry weather in spring and early summer.

In 1968 plots that were disked, fertilized, and seeded had significantly more plants (13.7 per quadrat) than disked and seeded plots (8.2 per quadrat), and the latter had significantly more than the average of other plots (0.2 per quadrat). Production of seed pods was directly related to number of plants. By 1969 plants were scarce or absent and there was no significant difference between any of the treatments in number of plants or seed pod production.

WILD SENSITIVE PLANT

1966 Seedings

In the fall of 1966 plants and seed pods per quadrat were significantly more numerous on seeded plots than on nonseeded plots (table 2). Neither disking nor fertilizing by themselves had a significant effect on plant numbers. Disking of seeded plots increased the number of pods, but fertilizing did not.

There were several plants on unseeded plots, indicating that this species was present before treatment.

The seed germination of 23 percent plus the natural occurrence of plants in the forest largely accounted for the greater number of wild sensitive plants in comparison to partridge-pea.

By 1967 only a few plants were present on the seeded plots (1.6 per quadrat) and the differences between treatments were not significant. In 1968 the plants and seed pods were sparse and remained so through 1969.

SOUTHERN FOREST EXPERIMENT STATION

1970

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SITE PREPARATION IMPROVES GROWTH OF PLANTED PINES

H. J. Derr and W. F. Mann, Jr. [1]

SOUTHERN FOREST EXPERIMENT STATION

At age 5 years slash pines planted on furrowed, flat-disked, and mound-disked plots were significantly taller and larger in diameter than those planted on unprepared plots on a Beauregard silt loam. The same site treatments improved diameter growth of loblolly pine, but differences in height were nonsignificant.

In the Southeastern States, bedding is a common method of site preparation on sandy flatwoods soils where the water table is at or near the surface for almost half of each year. Without this treatment, or extensive drainage, planted or seeded pines often fail to reach merchantable size. Bedding has been so effective that some landowners are beginning to use it on poorly drained, fine-textured soils in the west Gulf region. However, the effect of bedding on growth of pines in this area is is not known.

This note reports 5-year growth of loblolly (*Pinus taeda* L.) and slash (*P. elliottii* Engelm.) pines planted on mound-disked, flat-disked, furrowed, and unprepared check plots in central Louisiana.

[1] The authors are Principal Silviculturists at the Timber Management Research Project (1102), Alexandria Forestry Center, Pineville, Louisiana.

METHODS

Seedlings of both species were hand-planted in February 1964 on 0.4-acre plots. Preplanting site treatments were as follows:

Check. Seedlings were planted in an undisturbed heavy grass rough.

Furrowing. Furrows 3 to 4 inches deep and about 4 feet wide from edge to edge of the berm were plowed with a conventional fire unit 11 months before planting.

Flat disking. Strips were double-disked in the summer before planting with a 7-foot, heavy-duty offset disk that cut about 4 inches deep.

Mound disking. Also in the summer, plots were cut twice with a terracing disk that made mounded strips 7 feet wide and about 1 foot in elevation from the bottom to the crest.

Graded stock, obtained from the Louisiana Forestry Commission's Columbia nursery, was planted at 6-foot intervals in rows about 8 feet apart.

Soil on the test site is a Beauregard silt loam. Slopes up to 3 percent provide good surface

drainage, but internal drainage is slow. Water stands on the surface during the winter, but not for as long as on more typical flatwoods soils with slower internal drainage.

With each species the four site treatments were replicated three times in a randomized complete block design. Measurements were taken on interior plots that included 108 planted trees. Total heights of seedlings were measured 1, 3, and 5 years after planting, and at age 5 diameter at breast height was recorded along with the incidence of fusiform rust cankering. Average height of the 100 tallest trees per acre was computed for each plot from the array of all sample trees.

Differences between treatments were tested by analyses of variance (0.05 level of significance).

RESULTS

Slash Pine

None of the site treatments significantly influenced first-year survival of slash pine, which ranged from 83 percent on the check to 92 on the furrowed plots. Mortality during the following 4 years was low in all treatments, averaging 2 percent.

Site preparations were equally effective in promoting height growth, and all treatments combined were significantly better than the check (table 1). At age 5 years, slash pines averaged 10.3 feet on the unprepared plots and 11.5 to 11.9 feet on the prepared plots. Similar differences were found with the 100 largest trees per acre. They averaged 13.6 feet in height on the check and 14.8 feet on prepared plots.

The average diameter of all trees on the prepared plots was about 20 percent greater than on the controls (table 1). This difference was significant. Differences among site treatments, however, were small and nonsignificant.

The proportion of slash pines having fusiform rust stem cankers increased substantially from age 3 to 5 years. Site treatments influenced the incidence of this disease at age 5, with trees on mounded plots having about three times more infection than those on furrowed plots (table 2). Flat disking and the check were essentially alike, with 29 and 34 percent infection, respectively.

Table 2.—*Proportion of trees having one or more fusiform rust stem cankers 3 and 5 years after planting*

Site treatment	Trees with stem cankers at age:			
	3 years		5 years	
	Loblolly	Slash	Loblolly	Slash
	Percent			
Check	5.7	21.0	23.1	34.3
Furrowing	3.2	5.2	19.9	14.7
Flat disking	7.8	14.7	22.2	28.7
Mound disking	16.7	31.9	34.6	48.0
Species mean	8.4	18.2	25.0	31.4

Loblolly Pine

Initial survival of loblolly was high, averaging 92 percent for all treatments. However, it was about 11 percentage points lower on mound-disked plots than on the others—a difference that was significant. Mortality in the ensuing years was only 1 or 2 percent, and initial differences between treatments remained unchanged.

Table 1.—*Average tree size 5 years after planting* [1]

Site treatment	Average total height				Average d.b.h., all trees	
	All sample trees		100 tallest per acre			
	Loblolly	Slash	Loblolly	Slash	Loblolly	Slash
	Feet				*Inches*	
Check	9.4 a	10.3 a	11.9 a	13.6 a	1.14 a	1.65 a
Furrowing	10.7 a	11.9 b	13.9 a	14.9 b	1.54 b	2.00 b
Flat disking	10.2 a	11.6 b	13.0 a	14.4 b	1.46 b	1.96 b
Mound disking	10.5 a	11.5 b	13.7 a	15.1 b	1.62 b	1.94 b
Species mean	10.2	11.3	13.1	14.5	1.44	1.89

[1] Within a column, means that are not followed by the same letter are significantly different at the 0.05 level.

Trends in fifth-year heights seemed about the same in loblolly as in slash, but differences between treatments were not significant (table 1). Heights of all trees averaged 9.4 feet on the check plots and 10.2 to 10.7 feet on prepared plots. The 100 largest trees per acre averaged 13.1 feet.

Average diameters at 5 years were 28 to 42 percent greater on prepared than on check plots. All site treatments significantly boosted diameter growth about the same extent.

The percentage of stems infected with fusiform rust was less than in slash, but trends were about the same for both species (table 2). The disease was greatest on mounded plots, and least on those furrowed and flat-disked. Trunk infection was 50 percent greater on mounded plots than on the check.

DISCUSSION

This study is demonstrating some growth response to bedding and to the other site treatments tested on a Beauregard silt loam in central Louisiana. The planting site has relatively poor drainage, yet trees in furrows grew as well as those on elevated beds. After 5 years trees in furrows and on beds were 12 to 16 percent taller and 17 to 42 percent larger in diameter than trees on the untreated check. Clearly, the response cannot be attributed either to better or to poorer moisture conditions in the immediate vicinity of the planted trees. A comparable response on flat-disked plots suggests that some of it may be due to control of grass competition.

It is too early to tell whether costs of site preparation will be repaid by increased growth. So far, the growth differences between prepared and unprepared sites are not great, but they have been increasing with stand age. If they continue to increase, site preparation may prove economically advantageous. Each additional foot of height at age 30 years is roughly equivalent to 1 cord per acre, and stimulation of diameter growth shortens the time to a first thinning.

Of the site treatments tested, bedding has so far failed to show a clear advantage over the other two. It is expensive and considerably limits the ease of travel by fire-protection equipment and logging machinery. Furrowing has the same disadvantages and, in addition, increases the chances for serious flooding on poorly drained soils. Therefore, flat disking now appears to be the preferred treatment, even though it may increase the cost and difficulty of planting, especially when the soil is wet. These statements apply to Beauregard silt loams. Pines on other common flatwoods soils may respond differently. For example, where drainage is still poorer bedding may be more effective than in this study, and furrowing may be detrimental.

SOUTHERN FOREST EXPERIMENT STATION

1970

U.S. FOREST SERVICE RESEARCH NOTE

SO-107

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PROGENY OF LOBLOLLY PINE WOLF TREES DIFFER LITTLE FROM AVERAGE PROGENY[1]

Hoy C. Grigsby

SOUTHERN FOREST EXPERIMENT STATION

Ten-year-old progeny of eight wind-pollinated Pinus taeda *L. wolf trees did not differ significantly from woods-run controls in crown size, branch size, or natural pruning ability.*

A standard recommendation for seedsmen is that the fruits of wolf trees be avoided. The theory is that the broad crowns and short branchy boles may be passed on to the progeny. Thus, although loblolly pine *(Pinus taeda* L.) wolf trees are usually bountiful seed producers, collectors are seldom permitted to pick the easily harvested crop. Results presented here indicate that at least in some instances wolf tree seeds need not be avoided.

There is some indication that loblolly pine branching characteristics are heritable. In testing seed orchard progeny, Woessner[2] found some families with significantly smaller branches than others. Wolf trees, however, are usually found in understocked stands where their form may primarily reflect growing conditions.

METHODS

Eight 20- to 35-year-old loblolly pines with wide crowns, short stems, and large poorly pruned branches were selected in open stands along roads in southwestern Arkansas. Progeny of these trees were outplanted in the spring of 1957 in 10-tree rows paired with controls. Rows were replicated 12 times and spacing was 10 feet within and between rows to give the trees room to express their genetic constitution. Controls were from bulk nursery seed. Since loblolly pine cones are seldom collected from standing trees, it is unlikely that much of the bulk seed was collected from wolf trees.

After 10 growing seasons, all wolf tree rows and one randomly selected control row in each block were observed. Height and crown length of every second tree were measured to the

[1] Grateful acknowledgment is made to the Ozan Division, Potlatch Forests, Inc., for providing the planting site, and assisting in plot maintenance and data collection.

[2] Woessner, R. A. Growth, form, and disease resistance in four-year-old control- and five-year-old open-pollinated progeny of loblolly pine selected for use in seed orchards. N. C. State Univ. Tech. Rep. 28, 67 pp. 1965.

nearest half foot with a telescoping pole. D.b.h. was measured to the nearest 0.1 inch with a diameter tape on every tree. Crown diameter was obtained to the nearest half foot by averaging the diameters measured on the ground in north-south and east-west directions. The average branch size of each tree was observed and subjectively classed as large, medium, or small. Incidence of fusiform rust (*Cronartium fusiforme* Hedgc. & Hunt ex Cumm.) was recorded, and forking of the main stems was counted on six of the blocks.

RESULTS AND DISCUSSION

Analyses of variance revealed no significant differences (0.05 level) between wolf trees and controls in any of the traits observed.

Survival percentages ranged from 74.2 to 86.7 for the wolf trees. Control survival was intermediate at 81.5 percent.

Wolf tree heights varied from 31.1 to 33.6 feet; controls averaged 32.0 feet tall. Heights remained, in most cases, in the same relative positions they were at age 5.

Wolf tree progenies ranged from 6.82 to 7.40 inches d.b.h. The controls averaged 6.98 inches in diameter. As expected, diameters were closely correlated with heights.

Crown lengths varied from 19.5 to 22.3 feet. The controls were intermediate with an average length of 20.7 feet.

The variation in crown width was less than 2 feet, and again the control was intermediate with a width of 12.7 feet. Crown widths varied closely with height.

The total number of stem forks on six blocks ranged from 8 to 40 among the wolf tree progenies. The control had 16 forks. There appeared to be no relationship between the frequency of forking and the other observed features.

Fusiform rust infection ranged from 3 to 19 percent; the control had the highest infection rate. This was the only case in which a control trait was not near the median.

The most vigorous progeny ranked third in branch size, but in general this character was related to vigor. The control fell between the extremes, much as it did in growth rate.

There were significant differences among progenies of different wolf trees in crown width, crown length, d.b.h., and fusiform rust infection.

Since age 2, progenies of four of the eight wolf trees have maintained significantly greater height and crown length than the other four, but not greater crown width. These results indicate that a reasonably good assessment of height growth can be made at an early age, but that crown width takes longer to be expressed.

At age 10 none of the progenies had a combination of wolf tree traits. In fact, the progenies of two trees had some features that might justify them as candidates for plus trees.

Under the conditions of this study, phenotypic selection for wolf tree traits was ineffective. The results indicate that the form of the selected trees was more a function of environment than genetic constitution.

SOUTHERN FOREST EXPERIMENT STATION

1970

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PINE DIRECT SEEDING NOT IMPERILED BY FLORIDA HARVESTER ANTS

Thomas E. Campbell [1]

SOUTHERN FOREST EXPERIMENT STATION

Florida harvester ants foraged mostly empty seeds and spent seedcoats from germinated seedlings on areas sown to slash pine in Mississippi. Pine stocking was not improved significantly by eradicating ants before sowing.

Florida harvester ants *(Pogonomyrmex badius* (Latr.)) are seed predators, and they have been observed foraging pine seeds broadcast for reforestation in the Southeast *(1)*. Two studies were made in Greene County, Mississippi, in 1966 and 1967 to measure the impact of ant depredations on the success of direct-seeding operations.

METHODS AND RESULTS

The first study was established on a 17-acre tract that had an average of 5.6 ant colonies per acre. Ten plots, each 160 by 160 feet, were located so that each had a minimum of three nests and a 1-chain buffer strip around it. Plots were then paired by proximity. One plot of each pair was chosen at random for ant eradication; ants on the other plot were left undisturbed. All colonies on and within 1 chain of plots designated to be treated were fumigated with methyl bromide. The study area was within a large commercial seeding tract, on which 1¼ pounds or about 18,000 slash pine *(Pinus elliottii* Engelm.) seeds per acre were broadcast by helicopter in February 1966. Seeds were treated with bird, rodent, and insect repellents as described by Mann and Derr *(3)*.

Harvester ants did not cause a significant reduction in initial seedling stocking. The May 17-18 inventory showed 2,770 seedlings per acre on plots where ants were killed prior to sowing and 2,440 where ants were left to forage. Cooper et al. *(1)* found similar results with sand pine; ant control caused some increase in stocking, but the increase was not of practical significance.

An average of 9.8 pine seeds or remains of seeds were found deposited on the surfaces of 32 active mounds that were examined 3 months

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after sowing. Only 3.2 percent of the seeds were sound; the remainder were either empty seeds or spent seedcoats from germinated seedlings. Twenty colonies were examined in detail about 4 months after seeding. Seeds were collected from the surface, and each nest was excavated in layers. The soil was sifted through a fine-mesh wire screen to retrieve all contents. The bulk of material consisted of weed and grass seeds. An average of 35 pine seeds per nest were also collected, 23 of which were on the surface. Forty-nine percent of the pine seed were classed as spent seedcoats, 40 percent were empty, and only 11 percent were sound. Before the excavations it was suspected that unsound seeds were rejected within the cavity and returned to the surface. That theory proved unfounded. Sound seeds on the surface outnumbered those underground, and many empties and spent seedcoats appeared to be in storage chambers. Golley and Gentry *(2)* believed that harvester ants collect seeds in spring and summer for winter food. Apparently, workers indiscriminately gather seeds for storage without inspection for soundness.

Results of the first study showed that the threat of harvester ants to direct-seeded pines was more apparent than real. It was decided, however, that 66 feet of isolation might have been inadequate for fumigated plots. Cooper et al. *(1)* observed ants carrying seeds as far as 75 feet from their nests, and Van Pelt *(4)* noted foragers 100 feet from home.

A second study was done with isolation strips 100 feet wide. Ten plots, 280 by 280 feet, were mechanically located to insure at least one ant colony within the central 80- by 80-foot section of each. Plots were again paired by proximity, and the fumigation treatment was randomly assigned to one of each pair. Colonies per plot ranged from eight to 13. To provide for comparable depredations on each check plot, all nests in excess of eight were fumigated at the same time as those on treated plots. Depredations were therefore based on 4.4 active colonies per acre. Stratified loblolly pine *(Pinus taeda* L.) seeds were treated with bird, rodent, and insect repellents *(3)* and broadcast at the rate of 18,000 seeds per acre in February of 1967.

The seedbed was unfavorable—a 3-year grass rough—and 4 months after sowing there were only 333 seedlings per acre on untreated plots while treated plots averaged 444 per acre. Differences were not statistically significant.

Seed depredations were appraised in the second study by excavating two active colonies on each check plot. An average for each of the 10 nests were 196 seeds on the surface and 93 in underground chambers (fig. 1). Thirty-seven percent (107) of the total were either empty seeds or spent seedcoats from germinated seedlings. Another 38 percent (220) were half seedcoats, which may have been from 110 spent seedcoats or from good seeds opened and eaten by the ants. Seven percent (20) apparently started to germinate but failed to complete the process (seeds were slightly cracked open), and 18 percent (52) were full, ungerminated seeds. If all except the 106 empty seeds and spent seedcoats were potential seedlings, total depredations by 4.4 ant colonies per acre were only 4.5 percent of the sound seeds.

Figure 1.—*Partial excavation of a harvester ant nest revealed three pine seeds and five pieces of debris in an upper chamber.*

DISCUSSION

Until now, a forester who saw four to 10 Florida harvester ant nests per acre with up to 200 seeds around each had cause for concern. Results of the studies described should relieve that concern. A concentration of 4.4 to 5.6

colonies per acre did not significantly affect direct-seeding success. Most of the seeds found in nests were not viable when examined, and probably were not viable when they were foraged.

Why did the ants forage empty seeds and spent seedcoats? Careful observations showed that the ants did not become active until mid-April when daily maximum temperatures were consistently above 80° F. Most germination of the spring-sown seeds was complete by then. Only seeds that failed to germinate and spent seedcoats were available to forage, and harvester ants apparently did not distinguish full from empty seeds.

LITERATURE CITED

1. Cooper, R. W., Schopmeyer, C. S., and McGregor, W. H. D.
   1959. Sand pine regeneration on the Ocala National Forest. USDA Forest Serv. Prod. Res. Rep. 30, 37 p.
2. Golley, F. B., and Gentry, J. B.
   1964. Bioenergetics of the southern harvester ant, *Pogonomyrmex badius*. Ecology 45: 217-225.
3. Mann, W. F., Jr., and Derr, H. J.
   1964. Guides for direct seeding slash pine. USDA Forest Serv. Res. Pap. SO-12, 27 p. S. Forest Exp. Sta., New Orleans, La.
4. Van Pelt, A. F.
   1966. Activity and density of old field ants of the Savannah River Plant, South Carolina. J. Elisha Mitchell Sci. Soc. 82: 35-43.

SOUTHERN FOREST EXPERIMENT STATION

1970

U.S. FOREST SERVICE RESEARCH NOTE

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SEED YIELDS IN LOBLOLLY-SHORTLEAF PINE SELECTION STANDS

Charles X Grano

SOUTHERN FOREST EXPERIMENT STATION

In mature selection stands containing 12 to 92 square feet of basal area per acre in trees of seed-bearing size, seed yield per acre increased with seed-tree density up to 60-69 square feet. At higher densities seed production declined. Production per square foot of seed-tree basal area increased curvilinearly with decreasing stand basal area.

Trees of seed-bearing size are plentiful in mature selection stands of loblolly *(Pinus taeda* L.) and shortleaf pine *(Pinus echinata* Mill.), but the stands are often so dense that some have doubted that the trees could produce sufficient seeds of good quality. A study was undertaken in 1964 at the Timber Management Laboratory at Crossett, Arkansas, to investigate the seed yield and quality of loblolly-shortleaf pine selection stands of varying basal areas. This note reports the results of 4 years of observation.

METHODS

Fifty-one 0.3-acre plots were established in a mature loblolly-shortleaf pine stand that had been continuously managed under the selection system since 1937. The last cyclic cut occurred 4 years prior to study initiation. Ground litter remained undisturbed between cuts. The stand had not been burned for 30 years or more. A dense undergrowth of small hardwoods covered most of the area. The soil is Calloway-Grenada silt loam mounded. It is deep and poorly drained. Site index averaged 85 for loblolly pine. Stand basal area in trees of seed-bearing size, 9.5 inches d.b.h. and larger, ranged from 12 to 92 square feet per acre among the study plots.

One 1/20-milacre square seed trap was placed in the center of each 0.3-acre plot. A companion, circular milacre plot was established 10 feet north of each seed trap to determine initial seedling catch. Pine reproduction already on the milacre plots was removed. Seed counts were made weekly, starting with the 1964-1965 season and ending with the 1967-1968 crop. Seeds collected in any one season were pooled. The entire lot was stratified wet at 37° F. for 90 days and then subjected to a 28-day germination test. Total germination percent and Czabator's germination value

(GV), a measure of germination vigor or speed, were determined for each season's catch *(1)*. At the end of each test all ungerminated seeds were cut to determine how many were full.

Starting in 1965 and every year thereafter a seedling census was made early in June to assess initial catch. Survival counts were made in December. After each December count the seedlings were plucked and the census started anew the following June. No count was made in December 1968 because the study area was logged early that fall.

RESULTS AND DISCUSSION

Crops varied from 396,000 viable seeds per acre in 1966 to 25,000 in 1965 (table 1). Over the 4-year study period about 64 percent of the seed crop had fallen by the end of November and 82 percent by the end of December (fig. 1). The annual fluctuations in seed crops appeared to be about the same for open-grown seed trees as for selection stands. On two nearby seed-tree study areas, the within-season seedfall pattern was similar to that on the

Table 1.—*Seed production and quality*

Year	Seed yield per acre		Proportion of seeds germinating[1]		Viable seeds per acre	Germination value
	Total	Full seeds	All seeds	Full seeds		
	– *Thousands* –		– *Percent* –		*Thousands*	
1964	141.2	61.2	24.2	55.8	34.2	2.29
1965	65.9	27.5	37.5	90.0	24.7	8.76
1966	612.2	420.0	64.6	94.1	395.5	18.16
1967	390.6	231.8	29.3	49.4	114.4	2.65

[1] 28-day germination period after 90-day stratification.

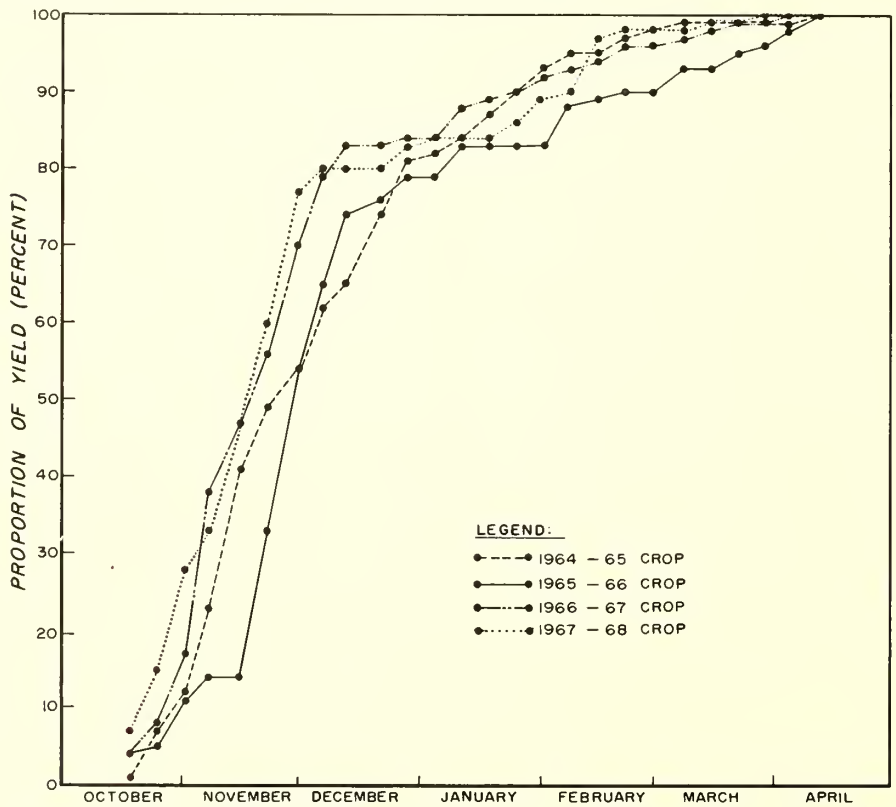

Figure 1.—*Cumulative proportions of seed yield for weekly periods.*

selection area. Of the 4 years, 1966 was the most fruitful and 1967 rated second.

The 1966 seed crop was also the best in quality. In other years crop size and seed quality were not consistently related. For example, the 1967 crop was large and 59 percent of the seeds were full, but less than half germinated.

Total and viable seed production per acre varied widely among plots within basal area classes. In general, however, total and viable seed production increased with increasing basal area up to densities of 60-69 square feet per acre (fig. 2). Production declined at stockings greater than 70 square feet per acre. The seed yield at 90-99 square feet did not conform to the general trend. However, only one plot was represented in this class and it could well have been atypical.

Production of viable seed per square foot of basal area increased curvilinearly as stand basal area decreased (fig. 3). The relationship is expressed by the regression equation $Y = 37.2 - 0.7563\ X + 0.0048\ X^2$, where Y = seed production in thousands and X = stand basal area. The coefficient of determination (R^2) was 0.60. Again, the range in seed production within basal area classes was broad.

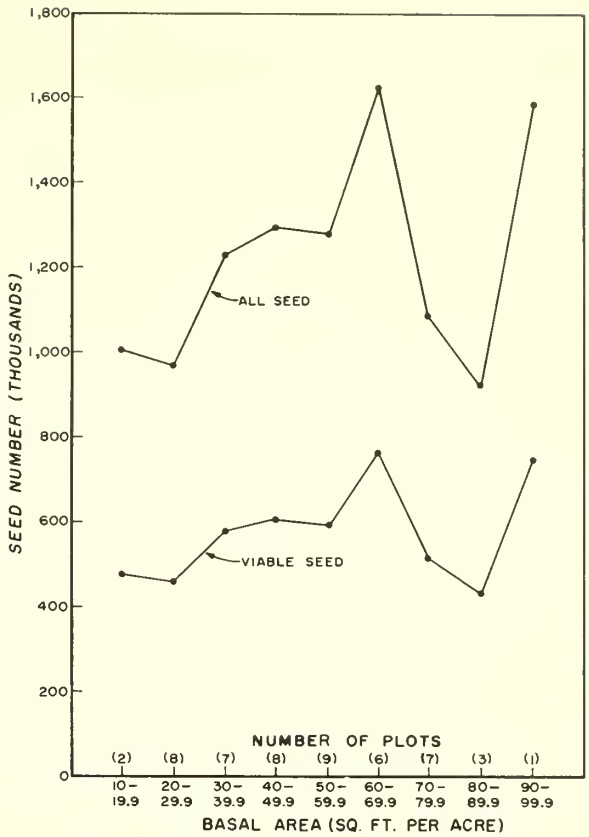

Figure 2.—*Four-year seed yield per acre in relation to stand basal area.*

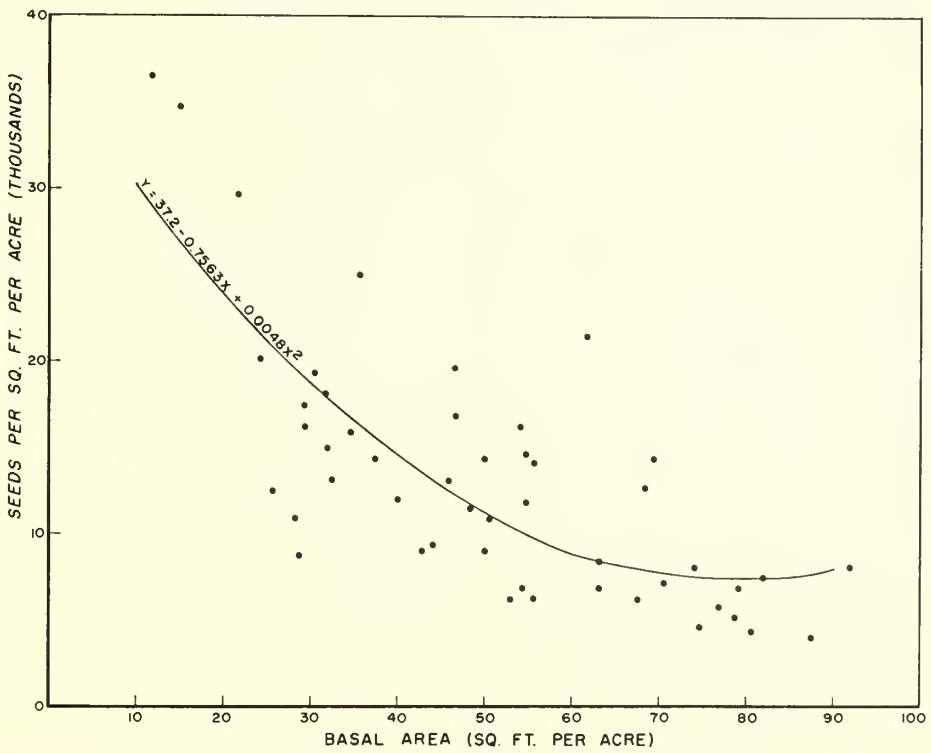

Figure 3.—*Four-year yield of viable seeds per square foot of seed-tree basal area in relation to stand basal area.*

Meager seedling catch combined with the exceedingly low proportion of plots stocked made it impossible to relate seedling catch to viable seed yield (table 2). Past investigation in this area showed that litter accumulation in unburned pine stands is not sufficient to prevent the initial establishment of many seedlings during years of abundant seed fall *(2)*. In the present case, heavy predation by mice or other seed consumers is suspected, but proof is lacking.

The study results show that mature loblolly and shortleaf pines can produce abundant seed over a wide range of seed-tree stocking. Production per acre is greatest at densities of from 60-70 square feet and decreases on either side of this peak. Individual trees are more productive in less crowded stands. An abundant supply of viable but unprotected seeds will not of itself ensure successful regeneration where seed predation is a problem.

LITERATURE CITED

1. Czabator, F. J.
   1962. Germination value: an index combining speed and completeness of pine seed germination. Forest Sci. 8: 386-396.

2. Grano, C. X.
   1949. Is litter a barrier to the initial establishment of shortleaf and loblolly pine? J. Forest. 47: 544-548.

Table 2.—*Seedling catch and stocking*

Item	1965	1966	1967	1968
		JUNE		
Seedlings per acre	176	98	922	392
Plots stocked—percent	15.7	7.8	29.4	27.4
Gross seed per seedling ratio	802:1	672:1	644:1	996:1
Viable seed per seedling ratio	194:1	252:1	429:1	292:1
		DECEMBER		
Seedlings per acre	39	59	608	
Plots stocked—percent	3.9	3.9	17.6	

SOUTHERN FOREST EXPERIMENT STATION

1970

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RESPONSE OF PLANTED LOBLOLLY AND SLASH PINE TO DISKING ON A POORLY DRAINED SITE

W. F. Mann, Jr., and H. J. Derr

SOUTHERN FOREST EXPERIMENT STATION

After 8 years on a Caddo-Beauregard silt loam, loblolly pines on flat-disked and bedded plots were 2.2 to 2.7 feet taller than those on unprepared check plots. Slash pines appeared to do best on bedded plots. In both species the responses to site treatment were consistent over the span of the study.

Mechanical site preparation is becoming prevalent on poorly drained, fine-textured soils in the lower Coastal Plains as landowners search for ways to improve productivity of pine plantations. On sites with heavy grass and only scattered hardwoods, shallow scalping, chopping, flat disking, and bedding (mound disking) are being tried.

A series of studies is in progress in central and southwestern Louisiana to measure growth of loblolly *(Pinus taeda* L.) and slash *(P. elliottii* Engelm.) pines on sites given various preparatory treatments. Individual studies are confined to soil types or complexes whose internal drainage varies from very slow to moderate. Reported here is the initial 8-year growth of a plantation on a Caddo-Beauregard silt loam, which has drainage about intermediate in the range under test.

The site is typical of nearly ½ million acres of forest land in southern Louisiana. The soil usually is saturated in winter but dries out rapidly in summer. Terrain is nearly flat, except for numerous "pimple mounds." Caddo and Beauregard soils are about evenly divided on the area, and many plots contain both types. When the study began the chief vegetation was heavy grass sod.

METHODS

To facilitate disking and planting, the entire area was burned in October 1959. Three treatments were installed:

Check—Undisturbed except for the burn.

Flat disking—Complete disking in the fall of 1960 and again in the summer of 1961 with a heavy-duty offset disk.

Bedding (mound disking)—Complete disking in the fall of 1960 followed by disking mounded beds about 8 feet apart, center to center, in the summer of 1961. After the soil settled, the beds were about 6 inches higher than the original surface.

Furrowing is a useful treatment on some poorly drained sites, but the study area was

so wet that water would have stood in furrows during much of the winter, making planting difficult and depressing growth.

In February 1962 plots were hand-planted at 6- by 8-foot spacing with seedlings from the State nursery at Columbia, La. Trees on bedded plots were placed on the peaks of the ridges.

Plots are 0.36 acre in size. Within each species treatments are replicated four times in a randomized complete block design.

Measurements have been confined to the center 100 trees on each plot. Total heights were measured annually, and diameters each year after age 5. Fusiform rust infection was recorded at age 8 years.

Differences between treatments were tested by analysis of variance, with 0.05 as the level of significance.

RESULTS

Survival

None of the site treatments significantly influenced first-year survival of either species. Survival of loblolly ranged from 74 percent on the check to 90 percent on bedded plots. Slash pine survivals were 82 percent on flat-disked plots and 89 percent on bedded plots. High survival was due to well-distributed rainfall in the summer of 1962.

Mortality in the next 7 years did not exceed 3 percentage points in any treatment. Most of the losses after the first year were caused by fusiform rust.

Height Growth

At age 8 years, the average heights of all loblolly trees on prepared plots were significantly greater than on the checks (table 1). The advantage was 2.2 feet for flat-disking and 2.7 feet for bedding. Heights of the 100 largest trees per acre followed the same general pattern, with trees in the disked and bedded treatments significantly taller—by 2.6 to 2.8 feet—than those in the check. These differences were also significant.

Slash pines on bedded plots averaged 2.5 feet taller than those on the check and flat-disked plots. While the difference was not statistically significant at age 8 years, growth on bedded plots has been so consistently superior over the span of the study that it appears to be a true response to treatment.

Table 1.—*Average tree size 8 years after planting, by species and site preparation* [1]

Site treatment	Total height		Diameter of all trees
	All trees	100 tallest trees per acre	
	Feet	*Feet*	*Inches*
	Loblolly Pine		
Check	25.9	29.3	4.30
Flat disked	28.1	32.1	4.51
Bedded	28.6	31.9	4.54
	Slash Pine		
Check	24.1	28.7	4.09
Flat disked	24.1	28.4	4.10
Bedded	26.6	30.6	4.46

[1] By Duncan's new multiple range test, means connected by the same vertical line do not differ significantly at the 0.05 level.

Annual height increment of both species increased sharply after the second growing season (fig. 1). Loblolly pine exceeded a rate of 5 feet per year between ages 6 and 8, and slash pine leveled off at slightly more than 4 feet per year.

Site treatment effects were not very pronounced on either species in the first 2 years after planting. In the following 2-year period, loblolly pine grew faster on flat-disked and bedded plots than on the check, while slash pine responded only on the bedded treatment. Bedding stimulated height growth of both species in the 4-year period from age 4 to 8, but flat disking had little effect except on loblolly pine in the final 2 years. The 8-year record does not reveal the full effect of intensive site preparation, for height differences are still increasing.

Slash pine is the usual choice for planting on Caddo-Beauregard soils in southern Louisiana, because it seems better adapted to poorly drained soils than loblolly. But in this study loblolly took the lead on the flat-disked and bedded plots during the sixth growing season, and 2 years later excelled on the check plots also.

To determine if soil type affected responses to site treatments, 8-year heights were sum-

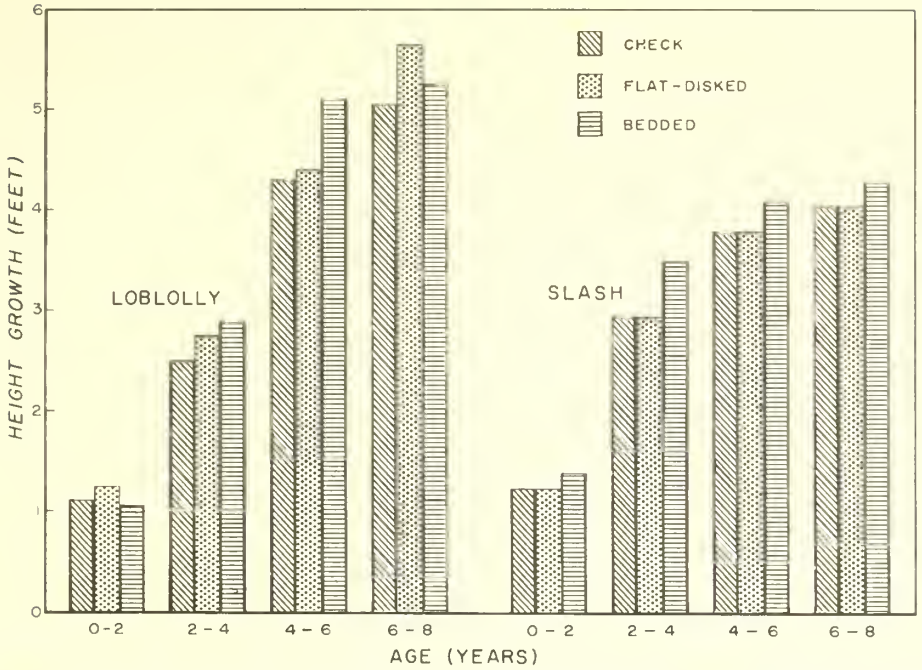

Figure 1.—*Height growth of loblolly and slash pines planted on bedded, flat-disked, and check plots.*

marized by the two soils. Both species were taller on the Beauregard than on the Caddo soil—the difference was 2.8 feet for loblolly and 1.7 feet for slash. Loblolly was taller than slash on both soils, with the differences averaging 2.1 feet on Caddo and 2.9 on Beauregard. Equally important, the differences in mean total height that resulted from intensive site treatment were about the same on each soil.

Diameter Growth

Average diameters of all trees at 8 years arrayed about the same as heights (table 1). Loblolly pines appeared somewhat larger on prepared plots than on the checks, but the differences were not significant. Slash pine diameters were 0.4 inch larger on bedded plots than on flat-disked and check plots—a difference that was significant.

Fusiform Rust Infection

The percentage of stems infected with fusiform rust was not related to site treatment with either species. Infection was five times greater on slash than loblolly, averaging 45 and 9 percent respectively.

To learn if the height differences between the two species might be related to the incidence of stem cankering, heights of disease-free trees were averaged on each plot. Loblolly in all treatments was still tallest after diseased trees were excluded. Cankered trees of both species were 1 to 3 feet shorter than healthy trees. Site treatments stimulated the growth of cankered and noncankered trees about the same.

DISCUSSION

It is still too early to judge if the treatments tested are economic on these soils. Loblolly has consistently made better height growth on the flat-disked and bedded plots than on the checks. So far, the two disking treatments are about equally effective. Slash pine has grown consistently better on bedded than on flat-disked and check plots.

It must be emphasized that results from this study apply only to Caddo-Beauregard silt loams with slow internal drainage. Responses to site treatments may vary with soil type and permeability. For example, another study of this series is on Beauregard silt loam of moderate permeability, and here pine growth in the first 5 years was about the same on sites prepared by flat-disking, bedding, and furrowing.[1]

[1] Derr, H. J., and Mann, W. F., Jr. Site preparation improves growth of planted pines. USDA Forest Serv. Res. Note SO-106, 3 p. S. Forest Exp. Sta., New Orleans, La. 1970.

SOUTHERN FOREST EXPERIMENT STATION

1970

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PROPERTIES OF ALLUVIAL SOILS SUPPORTING YOUNG STANDS OF EASTERN COTTONWOOD IN ALABAMA

Edwin H. White [1] **and Mason C. Carter** [2]

SOUTHERN FOREST EXPERIMENT STATION

In eight young cottonwood stands along streams and rivers in southwest Alabama, concentrations of extractable P, K, Ca, and Mg generally decreased with depth in the soil profile while percentages of coarse soil particles increased. Extractable soil K accounted for 94 percent of the variation in tree growth in seven of the eight stands studied.

Eastern cottonwood *(Populus deltoides* Bartr.) seems to have highly specific site requirements which are not yet well defined *(2, 3)*. This note reports textures, pH, and concentrations of extractable P, K, Ca, and Mg for soils supporting eight young, pure stands of cottonwood. The data presented here are useful mainly for comparison with that of soils being considered for cottonwood plantations.

[1] When this work was completed, Dr. White was Research Assistant in the Dept. of Forestry, Auburn Univ., Auburn, Ala., and partially supported by a Hardwood Forestry Research Fellowship from the Southern Pulpwood Conservation Assn. He is now Soil Scientist at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Miss., by the Southern Forest Experiment Station in cooperation with the Mississippi Agricultural Experiment Station and the Southern Hardwood Forest Research Group.

[2] Dr. Carter is Alumni Associate Professor in the Dept. of Forestry, Auburn Univ.

PROCEDURES

A survey was made of the floodplains of the lower Alabama and Tombigbee Rivers to locate pure young natural cottonwood stands. Eight stands, greater than 2 acres in area and representing a range of site quality, were selected. Their ages ranged from 6 to 9 years.

Two 1/20th-acre sample plots were established in each stand. On plots, each tree was numbered, its diameter was measured, and its crown position was classed as suppressed, codominant, or dominant. A table of random numbers was used to select one sample tree from each crown class on each plot for total tree and stem analysis as previously described *(6, 9, 11)*. Since it was desirable to remove the effect of stand age on tree height, the stem analysis data were used to derive the average height of the codominant and dominant trees at age 6, the age of the youngest stand *(4)*. Cubic-foot volumes of the sample trees were calculated from the stem analysis data and regression techniques used to estimate the volumes of uncut trees in the stands.

Duplicate soil samples were collected from soil pits by 6-inch depths to 2 feet and by 12-inch depths to 3 feet. All mineral soil samples were dried to a constant weight at 105° C. and passed through a 2-mm. sieve.

Soil pH was determined by glass electrode in a 1:1 soil:water mixture. P, K, and Mg were extracted from soil samples with a mixture of 0.05 *N* HCl and 0.025 *N* H_2SO_4. P was determined by the nitric acid-molybdate-vanadate procedure, K by flame spectrophotometry, and Mg by atomic absorption spectrophotometry *(10);* Ca was extracted with 1 *N* NH_4-OAc and the concentration determined by flame spectrophotometry; soil textures were determined by a combination of sieving and hydrometer by the method of Day *(1)*.

RESULTS AND DISCUSSION

The stands differed widely in productivity. Heights at age 6 for codominant and dominant trees ranged from 32.4 to 66.5 feet (table 1).

Extractable levels of soil P, K, Ca, and Mg generally decreased with depth in the profiles, while percentages of coarse soil particles increased (table 2).

Extractable soil K ranged from 28 to 180 p.p.m. and averaged 79 p.p.m. over all soils and depths sampled. Multiple regressions between site index (age 6) as the dependent variable and soil physical and chemical properties as the independent variables were computed. A positive relationship was found between height growth and extractable soil K in the 0- to 12-inch depth. The regression, while statistically significant, did not account for sufficient variation to be useful in predicting tree growth. Examination of the data showed that stand 3 deviated greatly from the regression line relating soil K to site index. The soils data indicated a sandy profile with low K status in relation to the other soils. Stand 3, being surrounded on three sides by the river and a slough, was influenced directly by a semipermanent high water table which may have supplied nutrients for the trees. Foliar nutrient levels in trees of stand 3 equaled or exceeded those in trees from the best sites, and foliar K levels were above suggested critical levels for the species *(12)*.

When data of stand 3 were omitted, a regression equation relating height growth to extractable soil K in the 0- to 12-inch depth in the other seven stands had an r^2 of 0.94:

$$\text{Site index} = 0.48\ (\text{p.p.m. soil K}) - 0.50$$

Previous work has shown that the foliar K levels of the sample trees were positively related to growth *(12)*. The indication that K status of the soils supporting the cottonwood stands is critical is in agreement with European experience indicating that *Populus* spp. have a high requirement for K *(5, 7, 8)*.

Soil pH values ranged from 5.7 to 7.0. Other reports have indicated that for adequate

Table 1.—*Mensurational data on young cottonwood stands on alluvial soils in southwest Alabama*

Stand [1]	Height at age 6	Height [2]	D.b.h.	Age	Stems	Basal area	Total volume
	– – – Feet – – –		*Inches*	*Years*	*No./acre*	*Sq. ft./acre*	*Cu. ft./acre*
1	66.5 a [3]	71.8 a	6.8 a	7	390 a	104	2566 a
2	56.8 b	65.6 b	5.7 b	8	470 a	89	2034 bc
3	55.4 b	58.2 cd	4.0 d	7	990 b	102	2116 b
4	50.1 c	60.6 c	4.8 c	9	610 a	80	1806 d
5	48.0 d	60.1 c	4.0 d	8	1090 b	103	2434 a
6	44.2 e	48.9 e	2.4 e	7	3280 c	88	1872 c
7	43.1 e	56.0 d	3.8 d	8	890 b	80	1581 e
8	32.4 f	32.4 f	1.3 f	6	7020 d	82	864 f

[1] Ranked 1-8 based on the basis of average height of codominant and dominant trees at age 6.

[2] Average height of codominant and dominant trees at stand age.

[3] Within columns, means followed by the same letter do not differ significantly at the 0.05 probability level.

Table 2.—*Properties of alluvial soils supporting cottonwood stands in southwest Alabama*

Stand [1]	Soil depth	pH	P	Ca	K	Mg	Sand	Silt	Clay	Textural class
	Inches		– *Parts per million* –				– *Percent* –			
1	0-6	6.4	7	4662	180	214	14	55	31	silty clay loam
	6-12	6.4	14	4343	103	180	33	43	24	loam
	12-18	6.5	12	3712	92	135	45	31	24	loam
	18-24	6.6	12	4312	79	146	55	29	16	sandy loam
	24-36	6.6	5	4388	82	169	50	30	20	sandy loam
2	0-6	5.7	4	3652	102	214	22	41	37	clay loam
	6-12	5.9	2	3130	99	172	12	45	43	silty clay
	12-18	6.1	2	3348	69	191	16	47	37	silty clay loam
	18-24	6.2	4	2592	72	191	26	39	35	clay loam
	24-36	6.0	3	2320	76	180	28	41	31	sandy clay loam
3	0-6	7.0	27	1955	52	105	80	15	5	loamy sand
	6-12	6.5	15	2885	58	146	68	22	10	sandy loam
	12-18	6.9	15	3028	50	122	78	14	8	loamy sand
	18-24	6.9	16	3024	42	126	65	23	12	sandy loam
	24-36	6.8	14	2600	50	120	68	22	10	sandy loam
4	0-6	6.5	10	3182	118	174	30	53	17	silt loam
	6-12	6.5	14	2752	79	154	35	46	19	loam
	12-18	6.6	10	3325	77	180	57	27	16	sandy loam
	18-24	6.6	12	2898	68	194	52	26	22	loam
	24-36	6.6	11	2300	66	180	51	27	22	loam
5	0-6	6.4	4	5034	92	272	14	54	32	silty clay loam
	6-12	7.0	7	7300	102	208	17	52	31	silty clay loam
	12-18	6.6	12	6600	80	218	29	40	31	clay loam
	18-24	6.6	10	5700	60	198	51	31	18	loam
	24-36	6.7	10	6725	78	196	54	30	16	loam
6	0-6	6.6	12	3390	142	199	36	46	18	loam
	6-12	6.4	14	981	53	67	93	6	1	sand
	12-18	6.2	13	2566	82	126	83	16	1	loamy sand
	18-24	6.4	10	2291	28	26	80	12	8	loamy sand
	24-36	6.3	12	1600	66	91	80	12	8	loamy sand
7	0-6	6.4	8	7475	97	262	14	53	33	silty clay loam
	6-12	6.5	9	7575	84	212	15	50	35	silty clay loam
	12-18	6.6	12	7850	83	200	22	45	33	clay loam
	18-24	6.7	12	4875	63	128	82	14	4	loamy sand
	24-36	6.6	12	3000	78	50	86	13	1	loamy sand
8	0-6	5.8	10	1890	92	169	68	23	9	sandy loam
	6-12	6.0	8	1825	66	130	64	22	14	sandy loam
	12-18	6.0	6	2055	52	132	68	18	14	sandy loam
	18-24	6.0	5	2400	64	135	59	25	16	sandy loam
	24-36	6.0	6	2500	65	140	60	23	17	sandy loam

[1] Ranked 1-8 based upon average height of codominant and dominant trees at age 6.

growth of *Populus* soil pH must be at least 5.5 *(5, 7, 8)*. Only two sites had soil pH values less than 6.4, and one of these was the poorest stand examined. Average soil pH over all soils and depths sampled was 6.4.

Extractable soil P ranged from 2 to 27 p.p.m. with an average over all soils and depths sampled of 10 p.p.m. H. A. van der Meiden *(8)* has reported that a level of 40 p.p.m. *total* soil P was adequate for the growth of *Populus* on fluvial sites in Holland.

Extractable soil Ca levels were three times greater in soil supporting the best stand than in soil supporting the poorest stand. However, large variations occurred in Ca concentrations in the other soils. Ca levels averaged over all

soils and depths sampled were 3,832 p.p.m. European experiences have indicated that high concentrations of Ca are important for adequate growth of *Populus (5, 7, 8)*.

Extractable soil Mg was variable over all sites, ranging from 105 to 272 p.p.m. Soil Mg averaged 167 p.p.m. over all soils and depths sampled.

LITERATURE CITED

1. Black, C. A., Evans, D. D. White, J. L., and others, editors.
   1965. Methods of soil analysis. 1572 p. Madison, Wisc.: Amer. Soc. Agron.
2. Broadfoot, W. M.
   1960. Field guide for evaluating cottonwood sites. USDA Forest Serv. S. Forest Exp. Sta. Occas. Pap. 178, 6 p.
3. Broadfoot, W. M.
   1969. Problems in relating soil to site index for southern hardwoods. Forest Sci. 15: 354-364.
4. Chapman, H. H., and Meyer, W. H.
   1949. Forest mensuration. 522 p. N. Y.: McGraw-Hill Book Co.
5. Food and Agricultural Organization of the United Nations.
   1958. Poplars in forestry and land use. FAO Forest. and Forest Prod. Stud. 12, 511 p.
6. Madgwick, H. A. I.
   1962. Studies in the growth and nutrition of *Pinus resinosa* Ait. Ph.D. Thesis. N. Y. State Coll. Forest. at Syracuse. 112 p.
7. Mayer-Krapoll, H.
   1965. The use of commercial fertilizers —particularly nitrogen—in forestry. 111 p. N. Y.: Allied Chem. Dye Corp.
8. Meiden, H. A., van der.
   1960. Handbook voor de populierenteelt. Ed. 3, 291 p. Arnhem, Ned.: Heidemij.
9. Ovington, J. D.
   1965. Organic production, turnover and mineral cycling in woodlands. Biol. Rev. 40: 295-336.
10. Perkin-Elmer Instrument Division.
    1966. Analytical methods for atomic absorption spectrophotometry. Norwalk, Conn.: Perkin-Elmer Instrum. Div.
11. White, E. H.
    1964. Uptake and distribution of nutrient elements in red pine plantations. M.S. Thesis. N. Y. State Coll. Forest. at Syracuse. 137 p.
12. White, E. H., and Carter, M. C.
    1970. Relationships between foliar nutrient levels and growth of young stands of *Populus deltoides* Bartr. *In* Tree growth and forest soils, p. 283-294. Third N. Amer. Forest Soils Conf. Proc. 1968, N. C. State Univ. Raleigh.

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GERMINATION INHIBITORS UNIMPORTANT IN DORMANCY OF SOUTHERN PINE SEEDS

J. P. Barnett [1]

SOUTHERN FOREST EXPERIMENT STATION

Bioassays of seed extracts and leachates revealed no evidence of a germination inhibitor in seeds of slash, shortleaf, spruce, or Ocala sand pine. Inhibitory activity was found in loblolly pine seed, but it did not appear to be the major cause of dormancy in these seeds.

Unstratified southern pine seeds of several species germinate over prolonged periods. The studies reported here were designed to learn whether germination inhibitors are a primary cause for this dormancy, which varies greatly by species and seed lot.

Relative dormancy, such as that exhibited in southern pines, is probably related to physical or chemical properties of the seedcoat *(5)*. Germination inhibitors in seedcoats are an important cause of dormancy in birch *(Betula pubescens* Ehrh. and *B. verrucosa* Ehrh.) seeds *(1)*, which respond to stratification in about the same manner as those of southern pines.

[1] The author is Principal Silviculturist at the Timber Management Research Project (1102), Alexandria Forestry Center, Pineville, Louisiana.

METHODS AND MATERIALS

Three seed lots for each of five species were tested. Slash *(Pinus elliottii* Engelm.), spruce *(P. glabra* Walt.), and shortleaf *(P. echinata* Mill.) seeds were fresh; Ocala sand pine *(P. clausa* [Chapm.] Vasey) seeds had been stored 5 years. Loblolly pine *(P. taeda* L.) seeds were evaluated in two separate studies with different seed lots. In the first study, the seeds were from lots 2, 3, and 6 years old. In the second study, seeds were fresh. Empty seeds were removed from all lots prior to the tests.

For the purposes of this paper, germination inhibitors are defined as stable chemical compounds that are soluble in methanol or water, and, when concentrated, restrict germination of decoated or nondormant seeds. Seeds and seed parts were leached in water, leachates were separated into their components by paper chromatography, and seeds were germinated on the various parts of the chromatograms. Where germination appeared to be inhibited, additional seed lots were extracted in meth-

anol, and the chromatographic and bioassay procedures were repeated on the extracts. This procedure is standard for demonstrating the presence of germination inhibitors *(3)*.

Lots of 200 seeds were macerated in a blender in 80 percent methanol. The homogenate was allowed to stand for 24 hours at 3° C., then the extract was filtered through a glass fiber. Extracts were prepared from intact seeds, decoated seeds, and seedcoats.

Seeds were leached by putting 30-gram samples into 1,000 ml. burettes, covering them with 5 cm. of sterile washed sand, and repeatedly cycling distilled water through the burettes for 2 weeks. Leaching was carried out in darkness at 15° C. As a control, seeds were imbibed for the same period and temperature on moist filter paper.

Extracts and leachates were concentrated at 35° C. with a flash-evaporator to about 2 ml. for chromatographic study. Chromatograms were developed on Whatman No. 1 paper using a solvent composed of 99 parts 70 percent aqueous isopropanol and one part ammonia. After the solvent front moved about 30 cm. the paper was dried. Since inhibitors are often fluorescent, chromatograms were examined under ultraviolet light. For bioassay, the paper was cut into 10 equal horizontal strips, approximating R_f values from 0.1 to 1.0.

Earlier dark-germination tests indicated that the reaction of decoated loblolly pine seeds and light-insensitive Simpson lettuce seeds *(Lactuca sativa* L.) were similar. In the bioassays lettuce seeds were substituted for pine seeds to avoid the difficulty of dissecting pine seeds and the problem of molding encountered in germinating decoated seeds.

Sections of chromatograms were moistened and put in individual petri dishes, and 50 seeds were placed on each section.

Since the presence of inhibitors does not necessarily imply a primary cause of dormancy *(4)*, further evaluations of the seeds were made to estimate the importance of inhibitory activity in dormancy. Leached and imbibed seeds were tested in darkness after exposures to red light ranging from 0 to 60 minutes. The assumption was that if germination was being controlled by an inhibitor leached seeds would germinate faster and with less light. Red light (wavelength of 660 $m\mu$) for irradiation treatments was obtained by filtering fluorescent light through two layers of 300 MSC red cellophane. The intensity of this irradiation was about 2,000 ergs/cm^2/second at seed level.

Tests were also made to evaluate any relationship between inhibitors and oxygen needs. An estimate of the effect of the seedcoat on gaseous exchange was made by germinating seeds after various stages of seedcoat removal. Seedcoat treatments were replicated three times on lots of 50 seeds. Treatments included puncturing, clipping, and removing seedcoats, as well as a control.

Germination of both pine and lettuce seeds was tested in darkness to avoid the complication of light effects and to enable critical evaluation of the treatment effects on dormancy. Tests were made on moist filter paper or chromatogram sections in sterile petri dishes that were held in lightproof cloth bags. Emerging seedlings were counted in a darkroom under a 15-watt fluorescent tube wrapped in a green gelatin filter having a peak transmission at 550 $m\mu$ *(6)*. The testing laboratory was maintained at a temperature of 22.5° C.

RESULTS AND DISCUSSION

No evidence of a germination inhibitor was found in aqueous leachates from seeds of slash, spruce, shortleaf, and Ocala sand pine. With these species, tests of leached and imbibed seeds given various exposures of red light were also negative.

Some evidence of an inhibitor was found in loblolly seed extracts and leachates, but the results are not fully consistent and do not show that the inhibitor is an important factor in the dormancy of these seeds. In the first study with loblolly seeds, the chromatograms of leachate inhibited lettuce seed germination in the area between R_f values of 0.9 and 1.0 (fig. 1). Dark germination on this section of the chromatogram averaged 58 percent, 15 percentage points less than the control and significantly less (0.05 level) than on all other sections of the chromatogram. Under ultraviolet light, fluorescent zones were present on chromatograms of both extracts and leachates at R_f 0.91, but only the leachate inhibited germination in this study.

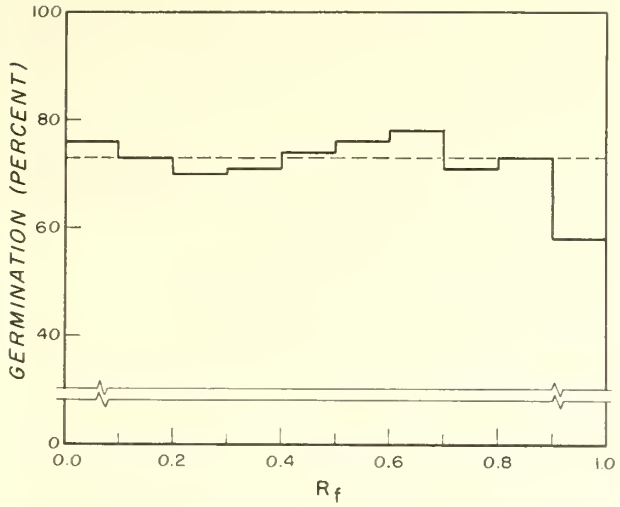

Figure 1.—*Germination of Simpson lettuce seeds in darkness on chromatogram of leachates of loblolly pine seeds. The broken line represents germination with no leachates present.*

In the second study with loblolly seeds the leachates did not inhibit germination, but some extracts did (table 1). In the bioassays, average germination of stratified and unstratified lettuce seeds was significantly less on extracts of seedcoats and whole seeds (88 and 89 percent) than on those of decoated seeds (94 percent). Thus, there seemed to be more inhibitor in the coats than in the seeds themselves. Differences in the bioassays due to stratification were not statistically significant.

On chromatograms of seed extracts, germination was significantly less on the section from R_f 0.9 to 1.0 than on the other sections (table 1). This position on the chromatograms is not associated with such specific inhibitors as abscisic acid and is likely to represent some phenolic compound.

Dark germination of leached and imbibed loblolly seeds subjected to stratification treatments and exposed to varying lengths of red light indicate that the inhibitor is not the major cause for dormancy. Exposure to red light increased germination of unstratified seeds (table 2). Leaching did not influence germination. A statistically significant interaction indicates, however, that leached unstratified seeds germinated better than imbibed unstratified seeds. The difference was small; germination averaged 22 percent for leached and 15 percent for imbibed seeds.

Table 2.—*Dark germination of leached and imbibed loblolly pine seeds after pregermination treatments and exposure to red light*

Minutes of exposure to red light	Leached		Imbibed	
	Strat.	Unstrat.	Strat.	Unstrat.
	Percent			
0	79	5	81	9
5	80	27	77	17
15	88	28	85	16
30	85	23	81	20
60	79	27	84	13
Avg.	82	22	82	15

Table 1.—*Dark germination of Simpson lettuce seeds on extracts and leachates of loblolly pine seeds*

R_f values of chromatogram sections	Extracts from						Whole-seed leachates	
	Whole seeds		Seedcoats		Decoated seeds			
	Strat.	Unstrat.	Strat.	Unstrat.	Strat.	Unstrat.	Strat.	Unstrat.
	Percent							
0.0 - 0.1	85	91	79	91	92	88	97	90
.1 - .2	88	87	91	96	92	89	93	96
.2 - .3	85	91	84	87	95	95	93	94
.3 - .4	92	93	92	93	92	96	89	95
.4 - .5	88	91	95	95	95	91	93	89
.5 - .6	88	79	88	89	95	91	93	95
.6 - .7	96	89	92	95	100	92	92	91
.7 - .8	96	88	92	81	92	99	93	97
.8 - .9	88	88	92	68	95	93	92	94
.9 - 1.0	84	77	81	69	89	92	95	93
Control	93	93	93	93	93	93	93	93
Average	90	88	89	87	94	93	93	93

Oxygen availability appears to be important in germination of loblolly pine seeds. Germination increased progressively with increasing degree of seedcoat injury from intact to decoated seeds (fig. 2). Differences among treatments were significant; 49 percent of decoated seeds germinated at 9 days as compared to 35, 4, and 0 percent of clipped, pricked, and intact seeds. It should be recognized that the differences in germination could have resulted from reductions in the mechanical restriction by the seedcoat as well as increased oxygen availability *(2)*.

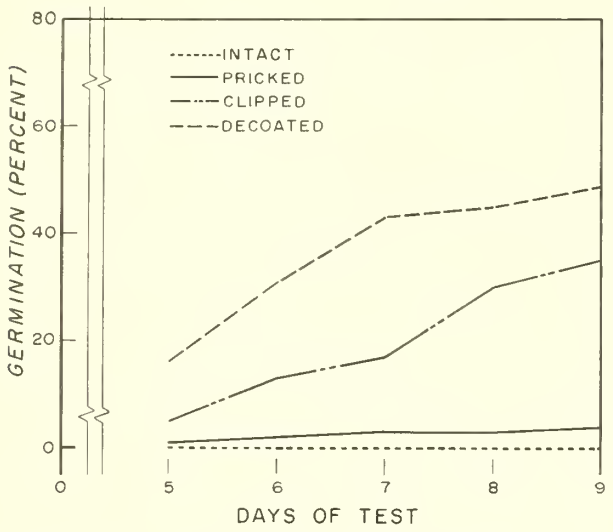

Figure 2.—*Dark germination of loblolly pine seeds after varying degrees of seedcoat removal.*

Black and Wareing *(1)* found that scratching birch seedcoats caused a greater increase in germination of leached than of imbibed seeds. Loblolly seeds did not react in this manner. Clipping affected germination of leached and imbibed seeds to about the same extent.

Chemical inhibitors apparently are not a major cause of dormancy in southern pine seeds. Although an inhibitor was extracted from loblolly seeds, the tests described indicate that it is not the primary agent controlling germination. Other factors, such as seedcoat permeability and mechanical constraint, probably contribute as much or more to dormancy of loblolly seeds.

LITERATURE CITED

1. Black, M., and Wareing, P. F.
   1959. The role of germination inhibitors and oxygen in the dormancy of the light-sensitive seed of *Betula* spp. J. Exp. Bot. 10: 134-145.
2. Ikuma, H., and Thimann, K. V.
   1963. The role of the seed-coats in germination of photosensitive lettuce seeds. Plant and Cell Physiol. 4: 169-185.
3. Leopold, A. C.
   1964. Plant growth and development. 466 p. N. Y.: McGraw-Hill.
4. Wareing, P. F.
   1965. Endogenous inhibitors in seed germination and dormancy. *In* Encyclopedia of plant physiol., p. 909-924. (W. Ruhland, ed.) Vol. 15, Part 2, Springer-Verlag, Berlin.
5. Wareing, P. F.
   1969. Germination and dormancy. *In* Physiology of plant growth and development, p. 603-644. (M. B. Wilkins, ed.) N. Y.: McGraw-Hill.
6. Withrow, R. B., and Price, L.
   1953. Filters for the isolation of narrow regions in the visible and near-visible spectrum. Plant Physiol. 28: 105-114.

SOUTHERN FOREST EXPERIMENT STATION

1971

U.S. FOREST SERVICE RESEARCH NOTE

SO-113

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VOLUME TABLES FOR SMALL COTTONWOODS IN PLANTATIONS

C. A. Mohn and R. M. Krinard [1]

SOUTHERN FOREST EXPERIMENT STATION

Tables present total cubic-foot volume inside and outside bark, volume outside bark to a 3½ inch top, and volume inside bark to a 3-inch top for plantation-grown cottonwoods up to 10 inches d.b.h.

Recently, eastern cottonwood (*Populus deltoides* Bartr.) has been planted extensively in the Lower Mississippi Valley, and accurate estimates of volume in small trees are needed to properly manage the plantations. This note presents volume tables for plantation trees up to 10 inches d.b.h. To ascertain volume, one need measure only total height and diameter at breast height.

SAMPLE TREES

The tables were developed from measurements of 650 sample trees in three plantations in the Mississippi River Valley near Greenville, Mississippi (Latitude 32° N). All trees were 3 or 5 years old. Age and diameter distributions of sample trees are given in table 1.

Table 1.—*Age, number, and diameter range of sample trees*

Plantation number	Age	Trees	Range of d.b.h.
	Years	*Number*	*Inches*
1	3	233	2.4-6.6
1	5	231	3.8-8.7
2	5	93	4.4-9.9
3	5	93	2.3-5.2

In all but one instance, sampled trees were selected on a mechanical basis in which both good and poor stems were equally likely to be cut. In Plantation 1 at age 5, selection was slightly biased toward small, poorly formed trees.

The fallen trees were measured, and volumes inside and outside bark were determined by summing volumes for 4-foot stem sections computed by Smalian's formula. In obtaining total tree volumes, the stump was treated as

[1] When the note was written, the authors were Plant Geneticist and Mensurationist at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Mississippi, by the Southern Forest Experiment Station in cooperation with the Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group. Mohn is now Assistant Professor, School of Forestry, University of Minnesota.

a cylinder and the tip as a paraboloid. Stump heights were determined from field measurements and averaged approximately 0.5 foot. Bark thickness was measured at 4-foot intervals beginning at stump height.

VOLUME EQUATIONS

Each of the four tables was constructed from a regression equation:

(1) Total volume outside bark = 0.21099 + 0.00221 D^2H ($r^2 = 0.988$)

(2) Total volume inside bark = —0.06477 + 0.00204 D^2H ($r^2 = 0.979$)

(3) Merchantable volume outside bark to a 3½ inch top = —0.57780 + 0.00219 D^2H ($r^2 = 0.982$)

(4) Merchantable volume inside bark to a 3-inch top = —0.62090 + 0.00204 D^2H ($r^2 = 0.973$)

D is diameter outside the bark at breast height and H is total tree height.

These equations, fitted to the data by least-squares regression, accounted for at least 97 percent of the variation in volume among the sample trees. Additional variables, such as stem form, bark thickness, and other functions of height and diameter, were examined by stepwise regressions. These accounted for such small proportions of variation in the dependent variables that they were not considered further.

Equation 3 was tested on 60 trees not used in its derivation. These trees had been cut while thinning from below in the Fitler plantations of the St. Francisville Paper Company. The trees were 6 and 7 years old when cut. They ranged from 4.2 to 9.9 inches d.b.h. and from 49 to 82 feet in height. In general, these trees had been far more crowded than those from which the equations were developed. They had been grown in seven different plantings at planting densities up to 1,200 per acre. The volume estimate with equation 3 was 7.7 percent above the measured volume. The relatively accurate result obtained with the regression equation, even when some trees exceeded the limits of the data, suggests that the tables may be suitable for a broad range of plantation conditions.

Table 2.—*Total cubic-foot volumes*[1] *outside bark for cottonwood in plantations*[2]

D.b.h. (inches)	Total tree height (feet)										No. trees measured
	25	30	35	40	45	50	55	60	65	70	
2.5	0.56	0.63	0.69								14
3.0	.71	.81	.91	1.01							16
3.5	.89	1.02	1.16	1.29	1.43						40
4.0	1.10	1.27	1.45	1.63	1.80	1.98					86
4.5	1.33	1.55	1.78	2.00	2.22	2.45	2.67				104
5.0		1.86	2.14	2.42	2.70	2.97	3.25	3.53			82
5.5		2.22	2.55	2.89	3.22	3.55	3.89	4.22			42
6.0			3.00	3.39	3.79	4.19	4.59	4.98	5.38		59
6.5				3.95	4.41	4.88	5.35	5.81	6.28		58
7.0					5.08	5.63	6.17	6.71	7.25	7.79	61
7.5					5.80	6.43	7.05	7.67	8.29	8.91	46
8.0						7.28	7.99	8.70	9.40	10.11	20
8.5						8.19	8.99	9.79	10.59	11.39	12
9.0							10.06	10.95	11.85	12.74	5
9.5								12.18	13.18	14.17	4
10.0								13.47	14.58	15.68	1

[1] Includes wood and bark of entire stem from ground to tip.

[2] Standard error of estimate = 0.283.

Table 3.—*Total cubic-foot volumes*[1] *inside bark for cottonwood in plantations*[2]

D.b.h. (inches)	Total tree height (feet)									
	25	30	35	40	45	50	55	60	65	70
2.5	0.25	0.32	0.38							
3.0	.39	.49	.58	0.67						
3.5	.56	.68	.81	.93	1.06					
4.0	.75	.91	1.08	1.24	1.40	1.57				
4.5	.97	1.17	1.38	1.59	1.79	2.00	2.21			
5.0		1.47	1.72	1.98	2.23	2.49	2.74	3.00		
5.5		1.73	2.10	2.40	2.71	3.02	3.33	3.64		
6.0			2.51	2.87	3.24	3.61	3.97	4.34	4.71	
6.5				3.38	3.81	4.24	4.68	5.11	5.54	
7.0					4.43	4.93	5.43	5.93	6.43	6.93
7.5					5.10	5.67	6.25	6.82	7.39	7.97
8.0						6.46	7.12	7.77	8.42	9.07
8.5						7.30	8.04	8.78	9.52	10.25
9.0							9.02	8.85	10.68	11.50
9.5								10.98	11.90	12.82
10.0								12.18	13.20	14.22

[1] Includes wood of entire stem from ground to tip.

[2] Standard error of estimate = 0.353.

Table 4.—*Cubic-foot volumes*[1] *outside bark to 3½ inch top for cottonwood in plantations*[2]

D.b.h. (inches)	Total tree height (feet)									
	25	30	35	40	45	50	55	60	65	70
4.0	0.30	0.47	0.65	0.82	1.00	1.17				
4.5	.53	.75	.97	1.20	1.42	1.64	1.86			
5.0		1.06	1.34	1.61	1.89	2.16	2.43	2.71		
5.5		1.41	1.74	2.07	2.40	2.73	3.07	3.40		
6.0			2.18	2.58	2.97	3.36	3.76	4.15	4.55	
6.5				3.12	3.59	4.05	4.51	4.97	5.44	
7.0					4.25	4.79	5.32	5.86	6.40	6.93
7.5					4.97	5.58	6.20	6.81	7.43	7.97
8.0						6.43	7.13	7.83	8.53	9.07
8.5						7.33	8.12	8.92	9.71	10.25
9.0							9.18	10.07	10.95	11.50
9.5								11.28	12.27	12.82
10.0								12.56	13.66	14.22

[1] Volume excludes stump 0.5 foot in height.

[2] Standard error of estimate = 0.349.

Table 5.—*Cubic-foot volumes*[1] *inside bark to 3-inch top for cottonwood in plantations*[2]

D.b.h. (inches)	Total tree height (feet)									
	25	30	35	40	45	50	55	60	65	70
4.0	0.20	0.36	0.52	0.68	0.85	1.01				
4.5	.41	.62	.82	1.03	1.24	1.44	1.66			
5.0		.91	1.16	1.42	1.67	1.93	2.18	2.44		
5.5		1.23	1.54	1.85	2.16	2.46	2.77	3.08		
6.0			1.95	2.32	2.68	3.05	3.42	3.79	4.15	
6.5				2.83	3.26	3.69	4.12	4.55	4.98	
7.0					3.89	4.38	4.88	5.38	5.88	6.38
7.5					4.54	5.12	5.69	6.26	6.84	7.41
8.0						5.91	6.56	7.21	7.87	8.52
8.5						6.75	7.49	8.22	8.96	9.70
9.0							8.47	9.29	10.12	10.95
9.5								10.43	11.35	12.27
10.0								11.62	12.64	13.66

[1] Volume excludes stump 0.5 foot in height.

[2] Standard error of estimate = 0.400.

SOUTHERN FOREST EXPERIMENT STATION

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GROWTH COMPONENTS OF ARKANSAS FORESTS

Daniel F. Bertelson

SOUTHERN FOREST EXPERIMENT STATION

Net growth of growing stock in Arkansas amounted to 758.6 million cubic feet in 1968. Of this total, 81 percent was survivor growth, 17 percent was ingrowth and growth on ingrowth, and 2 percent was growth on timber cut during the year.

Forest survey reports for Southern States contain estimates of net growth by species group and ownership class, but they do not provide estimates of growth for individual regions and they do not give the components of net growth. In Arkansas, the more than 5,000 survey plots established in 1959 were reexamined in 1969. Since changes in size and condition of individual trees were observed, it is possible to report here net growth and its components for the five survey regions of Arkansas in 1968.

The components are defined by the Forest Survey as: (1) survivor growth—the increment in net volume of trees in the growing stock at the beginning of the specified year and surviving to its end; (2) ingrowth—the net volume of trees at the time they grew into growing stock during a specified year; (3) growth on ingrowth—that increment in net volume of trees after they grew into growing stock in a specified year; (4) growth on removals—the increment in net volume of growing stock trees that were cut during the year; (5) mortality—the net volume in growing stock trees that died during the year.

Net growth is gross growth minus mortality.

Total gross growth was 826.9 million cubic feet (table 1). Of this amount survivor growth made up 75 percent, ingrowth and growth on ingrowth contributed 15 percent, and growth on trees cut during the year added another 2 percent. The volume of trees that died amounted to 68.3 million cubic feet, or 8 percent of the gross growth. Subtraction of this mortality leaves a total of 758.6 million cubic feet of net growth.

The Southwest survey region (fig. 1) contributed 55 percent of the total net growth. This region accounted for almost two-thirds of the softwood and over 40 percent of the hardwood net growth. The Ozark and Ouachita regions provided one-third of the total net growth. Timber stands in the North and South Delta added the remaining 12 percent.

Table 1.—*Growth components of growing stock by species group and survey region, Arkansas, 1968*

Survey region	Species group	Growth components					Total	
		Survivor growth	Ingrowth	Growth on ingrowth	Growth on removals	Mortality	Gross growth	Net growth
		Million cubic feet						
Southwest	Softwood	219.0	31.9	1.0	7.1	13.8	272.8	259.0
	Hardwood	127.7	25.6	.4	2.1	18.5	174.3	155.8
	Total	346.7	57.5	1.4	9.2	32.3	447.1	414.8
Ouachita	Softwood	73.5	13.8	.3	1.6	3.8	93.0	89.2
	Hardwood	32.2	13.9	.1	.9	3.3	50.4	47.1
	Total	105.7	27.7	.4	2.5	7.1	143.4	136.3
Ozark	Softwood	27.4	5.8	.1	.6	2.0	35.9	33.9
	Hardwood	56.4	21.5	(1)	1.5	10.2	89.6	79.4
	Total	83.8	27.3	.1	2.1	12.2	125.5	113.3
South Delta	Softwood	6.3	.5	(1)	.4	.1	7.3	7.2
	Hardwood	51.6	6.8	.1	2.4	10.9	71.8	60.9
	Total	57.9	7.3	.1	2.8	11.0	79.1	68.1
North Delta	Softwood	1.0	.2	(1)	(1)	(1)	1.2	1.2
	Hardwood	21.9	2.6	(1)	.4	5.7	30.6	24.9
	Total	22.9	2.8	(1)	.4	5.7	31.8	26.1
All regions	Softwood	327.2	52.2	1.4	9.7	19.7	410.2	390.5
	Hardwood	289.8	70.4	.6	7.3	48.6	416.7	368.1
	Total	617.0	122.6	2.0	17.0	68.3	826.9	758.6

[1] Negligible.

Figure 1.—*Forest survey regions in Arkansas.*

Table 2 expresses net growth as a percentage of the inventory volume of growing stock. As the inventory increases toward the carrying capacity, the net growth percent will decrease. In addition to the geographic area, growth percent is dependent upon the species occurring in that area. There is a wide variation in average growth rates among species. For instance, in 1968 loblolly pine had the largest growth rate, 7.9 percent, followed by shortleaf with 4.8 percent. The hardwoods were grouped together behind the pines. The oaks grew 4.3 percent and the gums 3.8 percent. All other hardwoods had an average growth rate of 4.3 percent.

Table 3 shows the growth components for major species groups. Loblolly and shortleaf pines, which are generally desirable, account for about one-half of the total net growth; their growing stock volume is 41 percent of the State total. Not all hardwoods are desirable, and the proportion of total growth occurring on desirable hardwood trees and species is small. For example, select oaks account for 37 percent of the total oak volume, and only 34 percent of the net oak growth. Also, the gums add 15 percent to the hardwood increment, but comprise about 17 percent of the total hardwood growing-stock volume.

Table 2.—*Net growth as a percentage of growing stock by survey region, 1968*

Survey region	Softwood	Hardwood
	– Percent –	
Southwest	6.8	4.9
Ouachita	4.6	4.8
Ozark	6.3	2.7
South Delta	4.9	4.7
North Delta	5.1	5.3
All regions	6.1	4.2

Average growth per acre in the State has increased from 37 cubic feet in 1958 to over 41 cubic feet in 1968. Each survey region, except the Ozark, showed an increase. The Southwest region averaged 62 cubic feet, an increase of 8 cubic feet per acre since 1958. The Ozark region averaged 18 cubic feet per acre, 2 cubic feet less than a decade ago.

Detailed information on timber volume and growth in Arkansas is available in recent publications of the Southern Forest Experiment Station. A statewide analysis is presented in "Arkansas Forest Resource Patterns," Resource Bulletin SO-24. Estimates of growth, volume, and acreage in individual counties are tabulated in "Forest Statistics for Arkansas Counties," Resource Bulletin SO-22.

Table 3.—*Net growth components of growing stock on commercial forest land for selected species, 1968*

Species	Net annual growth	Survivor growth	Ingrowth	Growth on ingrowth	Growth on removals
	– – – – – – – – Thousand cubic feet – – – – – – – –				
Loblolly pine	204,590	167,850	30,480	1,010	5,250
Shortleaf pine	173,570	149,220	19,710	330	4,310
Other softwoods	12,340	10,240	1,900	60	140
Select white oak	51,100	37,790	12,210	100	1,000
Select red oak	21,190	17,720	3,020	30	420
Other white oak	54,880	41,510	12,270	90	1,010
Other red oak	85,460	69,760	13,970	200	1,530
Sweetgum	40,600	32,320	7,230	70	980
Tupelo and blackgum	14,200	12,120	1,790	10	280
Pecan	790	770	(1)	(1)	20
Other hickories	47,310	38,470	7,870	40	930
Ash, walnut, and black cherry	14,190	11,290	2,620	10	270
Other hardwoods	38,400	28,100	9,360	110	830
Total	758,620	617,160	122,430	2,060	16,970

[1] Negligible.

SOUTHERN FOREST EXPERIMENT STATION

1971

U.S. FOREST SERVICE RESEARCH NOTE

SO-115

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SITE PREPARATION BOOSTS GROWTH OF DIRECT-SEEDED SLASH PINE

T. E. Campbell and W. F. Mann, Jr. [1]

SOUTHERN FOREST EXPERIMENT STATION

After 14 years, direct-seeded slash pines on mechanically prepared sites were taller, had larger diameters, and yielded more volume than those on grass roughs.

For many years disking has been recommended to prepare open, grassy areas in the West Gulf Coastal Plain for direct-seeding slash pine *(Pinus elliottii* Engelm. var. *elliottii)*. This treatment was considered necessary to reduce competition and prevent excessive mortality during droughts in the first year after seeding. Research results reported here indicate that disking is also justified because it stimulates growth. This conclusion is based on measurements in 14-year-old slash pine stands established by direct seeding on ground prepared in three ways. Growth of nursery seedlings planted adjacent to the study area is also given.

PROCEDURES

The study was designed to evaluate effects of sowing seasons as well as seedbed treatments on direct-seeding success. The study area is in central Louisiana on a Beauregard silt loam soil with fair internal drainage. Terrain is flat to gently rolling. The only ground cover, a dense stand of native grasses, was burned in the spring of 1954.

Six treatments, including all combinations of three seedbeds and two seasons of sowing, were replicated six times in a completely randomized design. Seedbeds were a light grass rough (burned), disked strips 6 feet wide and 7 feet apart, and plowed furrows 1.5 feet wide and 11 feet apart. Sowing dates were early November 1954 and late February 1955. Each 0.1-acre treatment plot was sown with 0.1 pound of seed. Seeds were evenly distributed over the burned plots, but they were confined to the prepared portion of disked strips and furrows. Seeds sown in February were coated with Morkit, an experimental bird repellent that did not prove to be effective, while those sown in the preceding November were untreated.

In the winter of 1954-55, 380 slash pine nursery seedlings were planted at a 6- × 6-foot spacing in two rows along each of two sides of

[1] The authors are Associate Silviculturist and Principal Silviculturist, respectively, at the 1102 TMR Project, Alexandria Forestry Center, Pineville, La.

the study area to compare height growth of seeded and planted trees. Planted trees were not included in the statistical design of the study.

Stocking at the end of the first growing season was estimated from 16 sample milacres on each plot. At age 5, all stems were counted on each treatment plot, and heights of all non-suppressed trees were measured. In 1968, when trees were 14 years old, all were again counted, and diameter, height, and crown position of trees with a d.b.h. of 4.6 inches and larger were measured. In the planted rows, diameters were measured on every other tree and heights on every tenth tree. Volumes of individual trees in standard rough cords to a 3-inch top diameter (i.b.) were obtained from table 27 of USDA Miscellaneous Publication 50.

Differences in stocking and size of trees at age 14 were tested by analysis of variance, with 5 percent as the level of significance. The relationships of cord volume and mean d.b.h. of merchantable trees to total trees per acre, by seedbed, were determined by regression analysis. The model was $Y = a + b(X) + c(X^2)$, where Y = volume per acre or average d.b.h. and X = total number of trees per acre in hundreds. Covariance analysis was used to determine whether seedbeds could be grouped together for volume and d.b.h. predictions, or if separate seedbed equations were needed.

RESULTS

First-year stocking on fall-sown plots ranged from 305 seedlings per acre in furrows to about 1,100 on disked and burned sites. Spring sowing was more effective—stocking averaged 630 on disked, 1,300 on furrowed, and 1,540 on burned plots. Treatment differences in stocking were caused mainly by seed losses rather than by early mortality. There was considerable variation within treatments.

Season of sowing had no influence on survival or growth after the first year, so fall and spring data were combined. Mortality from age 1 to 5 years averaged 36 percent on burned sites, 17 percent on disked strips, and 3 percent in furrows. Total height at age 5, excluding suppressed and diseased trees, averaged 5.4 feet on burned, 8.2 on disked, and 7.3 on furrowed seedbeds. At the same age, planted seedlings averaged 8.6 feet tall.[2] These early results showed that mechanical site preparation boosts survival and growth of young direct-seeded slash pines substantially, and that seedlings on disked and furrowed plots were almost as tall as the planted seedlings.

Differences in tree height due to site treatments remained about the same over the next 9 years (table 1). At age 14, heights of merchantable trees averaged 39 feet on disked, 38 on furrowed, and 36 on burned plots. Only the 3-foot difference between disked and burned plots was statistically significant. The same trend was found with dominant trees, although differences between treatments were slightly larger.

Diameters of merchantable trees on the two types of mechanically prepared plots averaged 0.3 and 0.4 inch larger than on burned plots. Since site-preparation effects on diameter might have been masked by wide variations in stocking within treatments, multiple regressions were run to isolate the influence of each. It was found that seedbed preparation significantly increased mean diameter when stocking differences were adjusted. Covariance analysis showed that prediction equations for each seedbed had a common slope, but that trees on disked and furrowed sites averaged 0.4 inch larger than on the grass rough at any level of stocking (fig. 1). Predicted mean d.b.h. of merchantable trees on these particular prepared sites was 7.2 inches in 300-tree stands and decreased gradually to 5.8 inches in stands of 1,800 trees per acre; comparable means for the grass rough were 6.8 and 5.4 inches.

The increased height and diameter growth on disked strips and plowed furrows is equivalent to about 1 year's increment, which is approximately 2 cords per acre on the study area. Another way to translate to volume is to assume each additional foot of total height adds about 1 cord per acre at age 30 years. The gain in site preparation estimated in this way is 2 to 3 cords per acre.

Average stocking was low for all seedbed treatments, ranging from 662 to 752 stems per acre at age 14 (table 1). Only 50 to 70 percent of these trees were merchantable size. However, many trees were just below 5 inches d.b.h., and they will become merchantable in a

[2] Russell, T. E., and Rhame, T. E. The advantages of disking for slash seeding. Forests and People 11(1): 12-13. 1961.

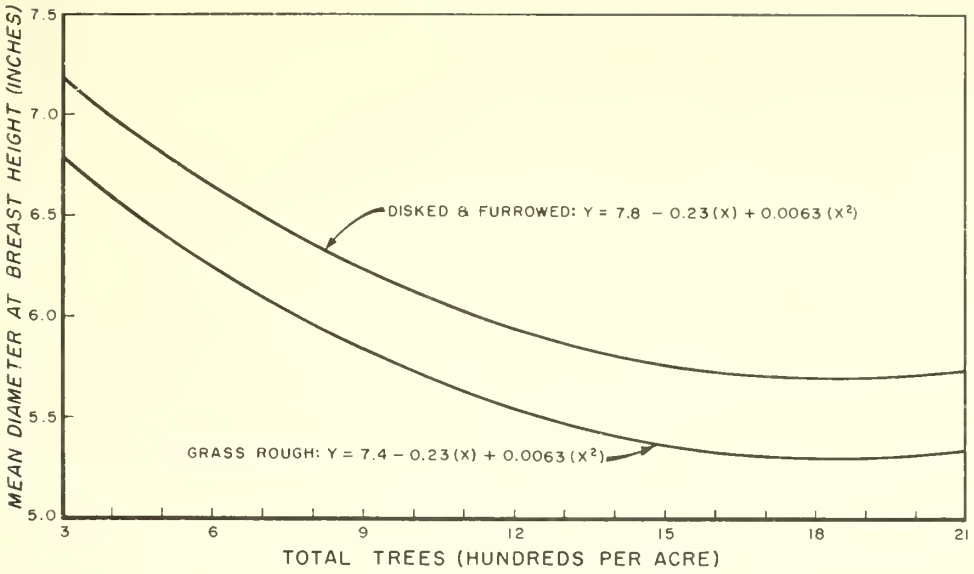

Figure 1.—*Influence of site preparation on the relationship between total trees per acre in hundreds (X) and the average diameter of merchantable trees (Y).*

Table 1.—*Stand data for planted and seeded slash pine at age 14*

Seedbed	Trees per acre			Mean total heights		Avg. d.b.h.—merchantable trees	Volume—merchantable trees
	All	Merchantable [1]	Dominant	Merchantable trees [1]	Dominant trees		
	Number			*Feet*		*Inches*	*Rough cords*
Seeded:							
Light rough	752	386	137	36 b [2]	39 b	6.3	13.1
Disked	662	444	143	39 a	43 a	6.6	19.2
Furrowed	697	377	136	38 ab	41 ab	6.7	15.2
Planted	441	441	248	38	41	7.8	24.1

[1] Trees 4.6 inches d.b.h. and larger.
[2] In columns, values followed by the same letter are not significantly different at the 0.05 level.

few years. Some small trees growing in clusters were hopelessly suppressed and will never grow to a usable size.

Although the stands were understocked, volumes averaged 13.1, 15.2, and 19.2 cords per acre on check, furrowed, and disked plots, respectively. Ranges in volumes on individual plots were great—2.4 to 25.6 cords on the checks, 7.2 to 24.0 in furrows, and 11.1 to 24.4 on disked strips. Since the greatest source of variation in volume within seedbed treatments was due to differences in stocking, multiple regression analyses were made to determine how stocking influenced volumes.

Covariance analysis showed that regressions for individual seedbed treatments had a common curvilinear slope, but differed significantly in level. Consequently, separate regression equations with a common slope were computed for each seedbed (fig. 2). These regressions account for 96 percent of the variation in volumes. They show that compared with burning, disking increased yields by 5.7 cords and furrowing increased it 2.8 cords per acre. The curves show that volume yields reach a peak in 14-year-old direct-seeded stands at about 1,600 trees per acre. At this level, yields are about 26 cords per acre on disked, 23 on furrowed, and 20 on burned seedbeds.

It is difficult to compare growth in the seeded and planted stands because diameter and volume are influenced greatly by the number of stems per acre, and the planted trees benefited from complete lack of competition

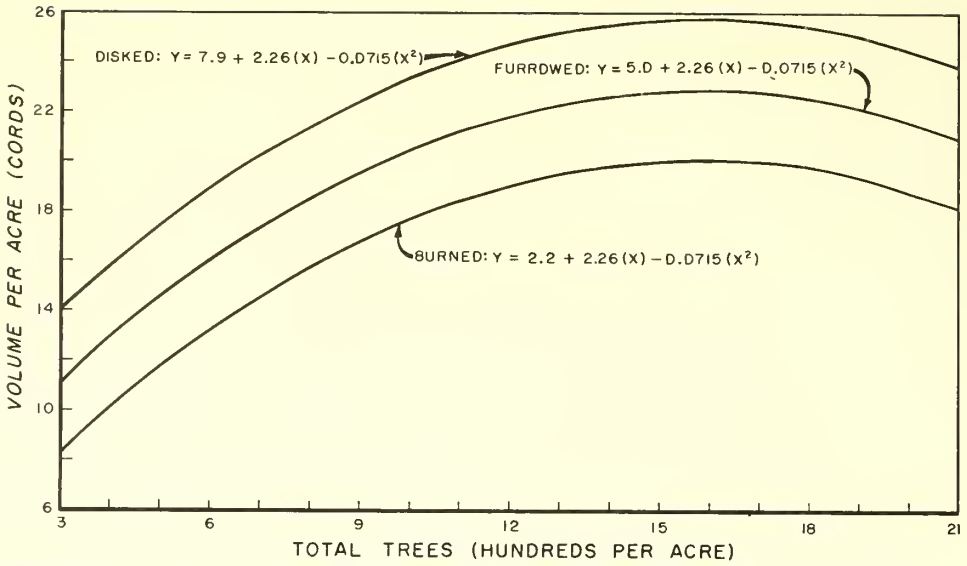

Figure 2.—*Influence of site preparation on the relationship between total trees per acre in hundreds (X) and cordwood volume per acre (Y).*

on the sides of both rows. The larger diameters of planted trees resulted in a substantial superiority in volume over seeded stands. Total height of trees in the upper crown classes provides the only valid comparison because it is unaffected by stocking. All planted trees had reached merchantable size at age 14 and they averaged 38 feet—the same as heights of seeded pines in furrows and 1 foot shorter than those on disked strips. Heights of dominant trees on disked strips averaged 2 feet greater than in the planted stand.

DISCUSSION

On open, grassy areas in the West Gulf Coastal Plain, disking prior to direct seeding slash pine is justified by increased growth as well as by reduced risk of drought losses. The extra growth of 2 to 3 cords per acre over nonmechanically prepared seedbeds will more than offset the cost of site preparation.

Furrowing was about as effective as disking in boosting height and diameter growth, but disking is preferable. Furrowing has a number of disadvantages: (1) seeds are easily washed away, (2) seeds are submerged and killed when water is trapped, (3) erosion may start unless the furrows are carefully oriented with contours, and (4) the land is left in such rough condition that access for fire fighting and logging is difficult.

Slash pines direct seeded on disked plots grew taller than planted trees by age 14, even though they were 1 year younger from seed. The difference in dominant trees was 2 feet, which is almost a full season's growth. On these sites, it seems that seeded trees quickly overcome the early height advantage of planted trees.

SOUTHERN FOREST EXPERIMENT STATION

1971

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SO-116

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CONDITIONING LOESSIAL SOILS FOR NATURAL LOBLOLLY AND SHORTLEAF PINE SEEDING

Charles X Grano

SOUTHERN FOREST EXPERIMENT STATION

On sites conditioned by logging alone, logging plus disking, bulldozing clean, and burning, loblolly and shortleaf pine seedling numbers and distribution varied directly with proportion of mineral soil exposed. Treatment benefits diminished greatly within 3 years.

Despite increasing popularity of direct seeding and planting, most loblolly *(Pinus taeda* L.) and shortleaf *(P. echinata* Mill.) pine stands continue to be reproduced through natural seedfall. In poor seed years, site conditioning is often needed to obtain sufficient regeneration, particularly when the seed tree method is used. This note reports the effects of four site-conditioning methods upon seed-to-seedling ratios in pine stands on loessial soil in southern Arkansas.

The two loblolly shortleaf pine stands studied contained an average of 8,700 board feet (International $^1/_4$-inch log rule) of saw logs and about six cords of pulpwood per acre. About 4,500 hardwoods per acre, mostly small, occupied the understory. One stand grew on soil classified as Calloway-Grenada silt loams, mounded. This is a deep, rather poorly drained loess consisting of friable silt loam over a slowly permeable silty pan. The soil in the second area is Calloway silt loam, which is a deep, somewhat poorly drained loess over a compact clayey pan. Site index in both stands averaged 85 feet for loblolly pine at age 50.

METHODS

Two contiguous blocks were located on each of the two soils. Site treatments were randomly assigned to one plot in each block. Treatment plots occupied 1 acre and a 1-chain-wide isolation strip surrounded each set of two blocks.

The four site treatments were: (1) summer logging only, (2) disking prior to summer logging, (3) bulldozing to mineral soil after summer logging, and (4) summer burning prior to logging. All surviving hardwoods 1 inch d.b.h. and larger were injected with a herbicide shortly after treatments (1) and (2) were completed. On the burned plots herbicide was injected the following May. Logging in 1966 removed all merchantable timber except nine seed trees per acre which averaged almost 19 inches d.b.h. About 5,600 board feet of saw-

timber and five cords of pulpwood per acre were harvested. One-pass disking was accomplished with a 1,450 pound Athens C-4 disk equipped with four bush and bog blades. Burning was done in July, with the wind, during a hot, dry period. Bulldozing cleared the plots of all logging debris and litter, exposing mineral soil.

Thirty-six 1/20-milacre seed traps and thirty ½-milacre circular sampling plots were installed on each treatment plot to inventory seed fall and seedling catch. Seeds caught each year were pooled by treatments, wet-cold stratified for 90 days, and tested for 28-day germination and vigor. Soon after treatment the seedbeds of all sampling plots were examined. Seedlings were inventoried yearly in December, and the reported stocking percents are based on the proportion of sampling plots which bore one or more seedlings. Differences among treatments in seedling numbers and stocking percents were tested for statistical significance at the 0.05 level.

RESULTS

Site alterations.—Bulldozing exposed mineral soil over almost all the area (table 1). Logging alone created the least surface disturbance, exposing mineral soil on 25 percent of the area. About a third of the disked and the burn areas were exposed. Because of the high volume of timber cut, logging itself mangled and destroyed the stems of almost all hardwood brush. Disking and burning inflicted additional damage. Bulldozing removed all hardwoods and in most cases tore out the roots. After treatment, only 4 percent or less of the study areas were overtopped by small hardwoods. Three years later overtopping ranged from 7 to 23 percent of plot area. At that time, the mineral soil originally exposed by disking, burning, and logging was found to be completely covered over with litter and small vegetation. Grass and pine needles occupied the bulldozed sites, but this material was so structured that seeds could sift through to mineral soil 3 years after treatment.

Table 1.—*Site conditions after treatment*

Treatment	Seedbed condition after treatment			Portion of area overtopped by hardwoods less than 1" d.b.h.	
	Mineral soil	Litter	Slash	After treatment	After 3 years
	Percent				
Log only	25	60	15	4	23
Disk + log	36	24	40	2	18
Bulldoze	96	4	0	1	7
Burn + log	31	44	25	2	16

Seed was plentiful and quality excellent throughout the study, averaging 167,000, 156,000, and 399,000 viable seeds per acre for the first, second, and third years. Germination vigor, measured by Czabator's Germination Value *(1)* was very high—21.80 in 1966, 25.97 in 1967, and 36.76 in 1968. About 77 percent of the total seed crop fell by the end of November and 92 percent by December's end—a normal pattern. There was no significant difference among treatments in the amount of viable seed produced per acre.

Seedling catch.—Bulldozing consistently yielded significantly more seedlings per acre than any other treatment (table 2). At the

Table 2.—*Seedling catch and stocking*[1] *in December inventories*

Year	Log only		Disk		Bulldoze		Burn	
	Seedlings	Stocking	Seedlings	Stocking	Seedlings	Stocking	Seedlings	Stocking
	M/acre	*Percent*	*M/acre*	*Percent*	*M/acre*	*Percent*	*M/acre*	*Percent*
1967	6.6	62.5	8.4	80.8	22.7	98.3	7.0	71.7
1968								
Residuals	4.0	..	6.0	...	17.2	.	4.7	...
New seedlings	1.2	.	2.4	..	9.5	..	1.8	.
Total	5.2	58.3	8.4	84.2	26.7	99.2	6.5	72.5
1969								
Residuals	5.0	.	7.5	.	19.1	..	5.9	...
New seedlings	1.0	..	3.3	.	14.8	..	2.2	...
Total	6.0	63.3	10.8	89.2	33.9	99.2	8.1	69.2

[1] Stocking percentages based on proportion of 0.5-milacre plots containing live seedlings.

close of the study there was no significant difference in seedling catch among the other treatments. Based on seedling numbers alone, all treatments produced enough, and bulldozing and disking more than enough seedlings for adequate regeneration.

It is well established that the beneficial effects of site conditioning diminish rapidly with time *(4, 5)*. In this study, the process was least pronounced on the bulldozed plots. Seedbed deterioration is best indicated by changes in viable seed-to-seedling ratios. In all treatments tested, the number of viable seeds required to produce one seedling increased yearly (fig. 1). Weather was not a factor in this trend. Growing season water supply was average for the first and third years of the study and especially favorable during the second year. Immediately after treatment, the site was most hospitable, and few viable seed were required to produce one seedling—seven on the bulldozed plots and 21 to 26 on the other plots. Bulldozing proved significantly superior in this respect to logging only and burning and logging. Results of other treatments did not differ significantly from each other. In 1968 the bulldozing treatment continued to be significantly better than burning and logging only. The seed-to-seedling ratio was significantly better on disked and burned plots than on those that were only logged. During 1969, and for the 3-year span collectively, the bulldozed plots required significantly fewer viable seed per seedling than the logged plots. The differences among other treatments were not significant after 3 years.

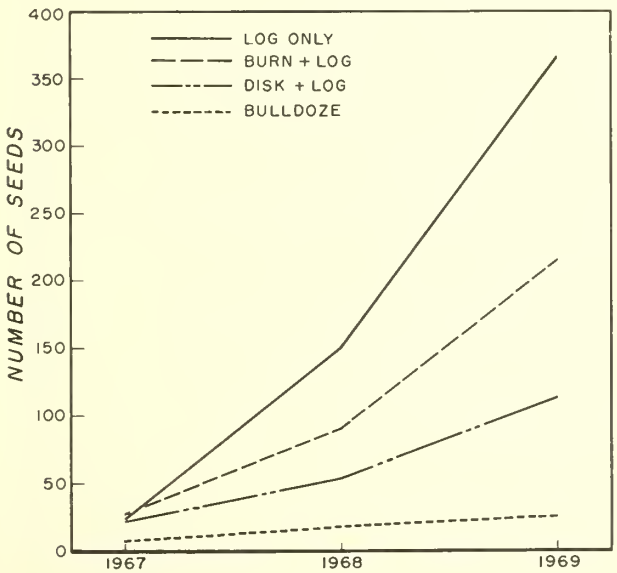

Figure 1.—*Number of viable seeds required to produce a seedling after each conditioning method.*

The percentage of 0.5-milacre plots stocked in each treatment changed very little after the first year (table 2). Final figures were bulldoze 99.2, disk 89.2, burn 69.3, and log 63.3 percent. The difference between bulldozing and disking treatments was not statistically significant, but both were superior to logging only and burning.

No relationship was found between the amount of mineral soil exposed and stocking percent. Regardless of treatment, 10 of 11 plots that had 30 percent or more mineral soil exposed initially ended up with 83 percent or more of their areas stocked. This result indicates that the distribution of the bare patches of soil is as important as the total proportion of areas exposed—a result previously reported in the Southeast *(2)*.

At the time of final inventory, 98 percent of the sample plots on the bulldozed areas bore seedlings unencumbered by overtopping brush. On other treatment areas the proportions were: disk 71.7, burn 55.8, and log-only 49.2 percent. The heights of the tallest seedlings on individual sampling plots averaged 2.0 feet for each treatment.

CONCLUSIONS AND RECOMMENDATIONS

Cutting in managed stands is usually scheduled years in advance and harvests must often be made when the seed crop is sparse. When this happens in even-aged stands, site conditioning is needed to maximize seedling catch and survival. Bulldozing and disking are highly effective, but both require heavy machinery and are expensive *(6)*. In the study described, seedling catch and distribution were not improved significantly by burning before logging. The lack of improvement is attributable mainly to the large volume of timber logged and to killing of hardwoods with herbicide after the logging-only treatment. In general, burning can be expected to improve seedbeds and improve stocking, particularly if the timber cut is light. Two or more annual burns prior to harvest cutting provide good seedbed condi-

tions and a high degree of hardwood control at very low cost *(3, 6)*.

There is no universal site treatment adequate for all seed years and stand conditions. Data presented here should help the land manager to choose an economical conditioning method that will assure a well-stocked new stand.

LITERATURE CITED

1. Czabator, F. J.
   1962. Germination value: an index combining speed and completeness of pine seed germination. Forest Sci. 8: 386-396.
2. McCulley, R. D.
   1953. Natural regeneration of loblolly pine in the southeastern Coastal Plain. USDA Forest Serv. Southeast. Forest Exp. Sta., Sta. Pap. 26, 14 p.
3. McNab, W. H., and Ach, E. E.
   1967. Prescribed burning improves Piedmont loblolly pine seedbeds. USDA Forest Serv. Res. Note SE-76, 2 p. Southeast. Forest Exp. Sta., Asheville, N. C.
4. Trousdell, K. B.
   1954. Favorable seedbed conditions for loblolly pine disappear 3 years after logging. J. Forest. 52: 174-176.
5. Trousdell, K. B.
   1963. Loblolly pine regeneration from seed. What do site preparation and cultural measures buy? J. Forest. 61: 441-444.
6. Trousdell, K. B., and Langdon, O. G.
   1967. Disking and prescribed burning for loblolly pine regeneration. J. Forest. 65: 548-551.
7. Wenger, K. F., and Trousdell, K. B.
   1957. Natural regeneration of loblolly pine in the South Atlantic Coastal Plain. USDA Prod. Res. Rep. 13, 78 p.

SOUTHERN FOREST EXPERIMENT STATION

1971

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HYDROLOGIC CHARACTERISTICS OF SMALL HEADWATER CATCHMENTS IN THE OUACHITA MOUNTAINS

T. L. Rogerson [1]

SOUTHERN FOREST EXPERIMENT STATION

Precipitation, runoff, and sediment losses were measured for 9 years and soil water for the last 3 years on three small forested catchments in the Ouachita Mountains of central Arkansas. Annual precipitation averaged 52.5 inches and runoff 6.0 inches. Seventy-seven percent of the runoff occurred during the December-May periods when soil water was near maximum capacity. Annual sediment losses averaged 13.8 pounds per acre.

The growing population, industries, and recreational economy of west-central Arkansas depend the year around upon an adequate water supply from the Ouachita Mountains. However, streamflow is usually very low during late summer and fall. This paper reports the results of a 9-year study in which hydrologic data were collected prior to testing management practices to increase streamflow during summer and fall.

[1] The author is Associate Hydrologist, Southern Forest Experiment Station, Fayetteville, Arkansas.

STUDY AREA

Three adjoining catchments 1.63, 1.28, and 1.44 acres in size were selected for hydrologic studies in 1960. They are on a northeast aspect between 1,300 and 1,400 feet in elevation and have a slope of 15 percent. The catchments have similar soils and topography (fig. 1). Soil types are Goldston, Herndon, Alamance stony loams. The soils are shallow (2½ to 3 feet deep) and moderately permeable. Water storage capacity is low due to the thin solum. Parent material is predominantly uplifted shale with some sandstone interbedding.

Vegetation on the catchments consists of a shortleaf pine (*Pinus echinata* Mill.) overstory and a mixed hardwood understory. The understory contains white oak (*Quercus alba* L.), red oak (*Quercus rubra* L.), blackgum (*Nyssa sylvatica* Marsh.), dogwood (*Cornus florida* L.), hickory (*Carya* spp.), and red maple (*Acer rubrum* L.). When inventoried in 1964, the pine overstory had 287 stems per acre and a basal area of 98 square feet per acre. The

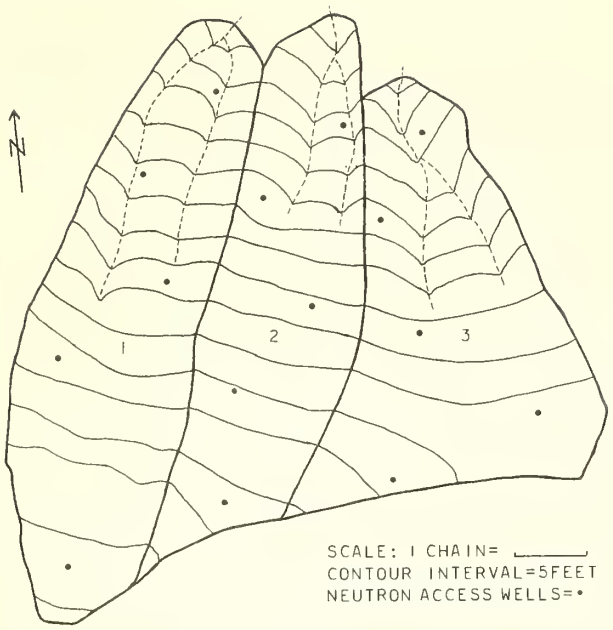

Figure 1.—*Experimental catchments, Alum Creek Experimental Forest.*

hardwood understory had 960 stems and a basal area of 29 square feet per acre. When reinventoried in January 1970, the pine overstory had 275 stems per acre and a basal area of 105 square feet. The understory had 1,085 stems and a basal area of 34 square feet per acre. Pine-hardwood litter covered the forest floor to a depth of about 2 inches.

In the study area summers are hot and the short winters are moderately cold. Annual precipitation on the study area averaged 52.5 inches for the 1961-1969 period and ranged from 39.3 inches in 1963 to 66.0 inches in 1968. Annual precipitation at the Alum Fork climatological station 10 miles east of the catchments has averaged 55.2 inches during the past 25 years. Precipitation is distributed fairly evenly throughout the year except for the month of October, which usually has less than 3 inches. Almost all precipitation is in the form of rain but light snow falls a few times each year. Mean annual temperature is 62.1° F.; the January mean is 42.3° and the July mean is 81.6°. Average growing season is 214 days from March 30 to October 30.

EVAPOTRANSPIRATION

Evapotranspiration, the sum of evaporation of intercepted precipitation, evaporation from soil surfaces, and transpiration from vegetation, averages about 34 inches annually on the catchments as calculated by the Thornthwaite and Mather *(3)* method.

Interception was studied on the catchments during 1962-1964 *(2)*. Total interception by the pine-hardwood cover averaged 15.1 percent of average gross precipitation and stemflow 2.4 percent. Average annual interception loss, therefore, was 12.7 percent, or an average of 7 of the 55.2 inches of annual precipitation.

Potential and actual evapotranspiration calculated by the Thornthwaite method are plotted in figure 2. Average temperature and precipitation data in these computations are from the Alum Fork climatological station to the east of the study area. There is a water surplus from mid-December until early June. This water is over and above that needed to satisfy potential evapotranspiration while maintaining soil water at field capacity. Water surplus becomes runoff or deep seepage. From June until October precipitation is less than

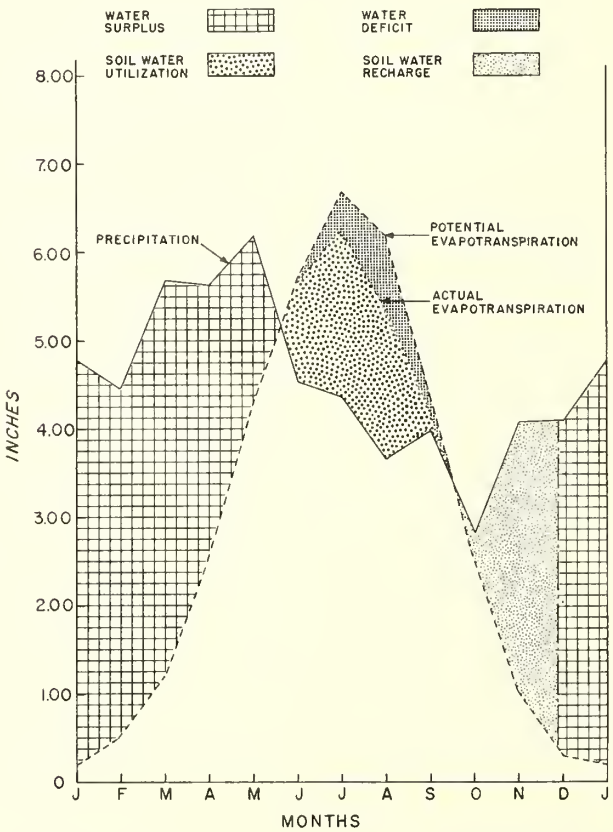

Figure 2.—*Average monthly precipitation and potential and actual evapotranspiration for Alum Creek climatological station, 1944-1969.*

potential evapotranspiration and soil water is utilized for evapotranspiration. As soil water reserves are depleted, actual evapotranspiration becomes less than potential evapotranspiration and a water deficit occurs. Soil water recharge begins in October (when precipitation is greater than potential evapotranspiration) and is completed by mid-December.

RUNOFF

Runoff from the catchments is measured in 3-foot H-flumes. Stages are measured with FW-1 water-level recorders and are converted to cubic feet per second and area-inches for each storm. Flow from the catchments is intermittent and between 0.75 and 2.00 inches of precipitation usually fall before runoff begins. The amount of rainfall required to initiate runoff depends mainly on rainfall intensity and amount of water in the soil. Changes in rainfall intensity are quickly evidenced in discharge rates, and recession periods are short because the catchments are small.

During the 9 years of study, annual runoff ranged from 3.1 inches in 1963 to 9.4 inches in 1968 and averaged 6.0 inches. Annual precipitation and average annual runoff from the three catchments have been closely related. Runoff is low between June and November, even though precipitation is well distributed throughout the year (table 1). Precipitation for this period has averaged 25.4 inches or 48 percent of the average annual rainfall. Runoff in these months has only averaged 1.4 inches or 23 percent of the average annual runoff. Precipitation between December and May has averaged 27.1 inches or 52 percent of the average annual precipitation. Runoff in these months has averaged 4.6 inches or 77 percent of the average annual runoff.

Table 1.—*Mean monthly precipitation and runoff for Alum Creek catchment, 1961-1969*

Month	Rainfall	Runoff
	– – – Inches – – –	
January	3.57	0.84
February	3.70	.56
March	5.40	1.28
April	4.70	.66
May	5.68	.79
June	3.77	.05
July	5.41	.46
August	4.81	.28
September	4.22	.23
October	2.68	.01
November	4.52	.34
December	3.99	.51
Total	52.45	6.01

Low runoff from June through November is attributed to high evapotranspiration losses and the need to recharge soil water during October and November. Evapotranspiration, as calculated by the Thornthwaite method, is 25 inches during the June-November period, or 74 percent of the annual evapotranspiration, while the evapotranspiration loss from December through May is only 9 inches, or 26 percent. As an example, the mean monthly precipitation in March and July is the same but mean July runoff is only one-third that of March.

Peak discharges have exceeded 1.00 c.f.s. nine times on catchment 1 and five times on catchments 2 and 3 from 1961 through 1969. Rainfall in excess of 2.5 inches and 15 minute intensities of greater than 2.4 inches per hour are usually recorded when discharge rates exceed 1.00 c.f.s. Maximum peak discharges of 3.03, 2.14, and 2.15 c.f.s. were recorded for catchments 1, 2, and 3 on September 21-22, 1963. On these dates 8.25 inches of rain fell in less than 24 hours and a 15-minute intensity of 3.28 inches per hour was measured.

SEDIMENT

Sediment suspended in runoff from the catchments is measured with Coshocton samplers and filtering devices *(1)*. The instruments are set to begin sampling runoff at a stage of 0.12 foot (0.047 c.f.s.) because stages of less than this value contain very little sediment. Deposited sediment and that remaining in the flumes and approach sections after a runoff event also have been measured. Sediment losses as discussed herein are the sum of suspended and deposited material.

Sediment losses from the three catchments have averaged 13.8 pounds per acre per year during the 1963-1969 period. Average annual losses have ranged from 26.4 pounds per acre in 1968 to 5.57 pounds per acre in 1963. Variances in annual losses are attributed to year-

to-year differences in storm sizes, rainfall intensities, and discharge rates. Discharge rates in excess of 0.50 c.f.s. occurred in only 11 percent of the runoff-producing storms but they accounted for 68 percent of the sediment losses. The remaining 89 percent of the runoff-producing storms, those with peak discharges of less than 0.50 c.f.s., produced 32 percent of the sediment losses.

Sediment losses were considerably higher (103.3 and 65.7 lbs./acre) for the 2 years following installation of the flumes. Apparently, the sites were disturbed during flume construction. Data from these years were not used in determining average sediment losses.

SOIL WATER

Soil water has been measured in five neutron access wells on each catchment since 1967. The wells were installed to bedrock (2½ to 3 feet deep) at selected slope positions (fig. 1). Measurements are made at approximately weekly intervals at a depth of 9 inches and at 6-inch increments to bedrock. Soil water as discussed herein refers to average water in the profiles from a depth of 6 inches to bedrock.

Maximum soil water measured on the catchments was 11.2 inches on May 15, 1968. This total is roughly 0.5 inch greater than the estimated field capacity of 10.7 inches. Minimum soil water recorded to date was 7.3 inches on September 29, 1969.

Figure 3 shows the amounts of precipitation, runoff, and soil water deficit from maximum soil-water capacity for 1968. This figure indicates that nearly all runoff occurs when the soil water deficit is less than 1 inch. The soil water deficit is usually less than 1 inch throughout the December-May period when 77 percent of the runoff occurs. Small amounts of runoff occur at other times when heavy rainfall reduces the soil water deficit.

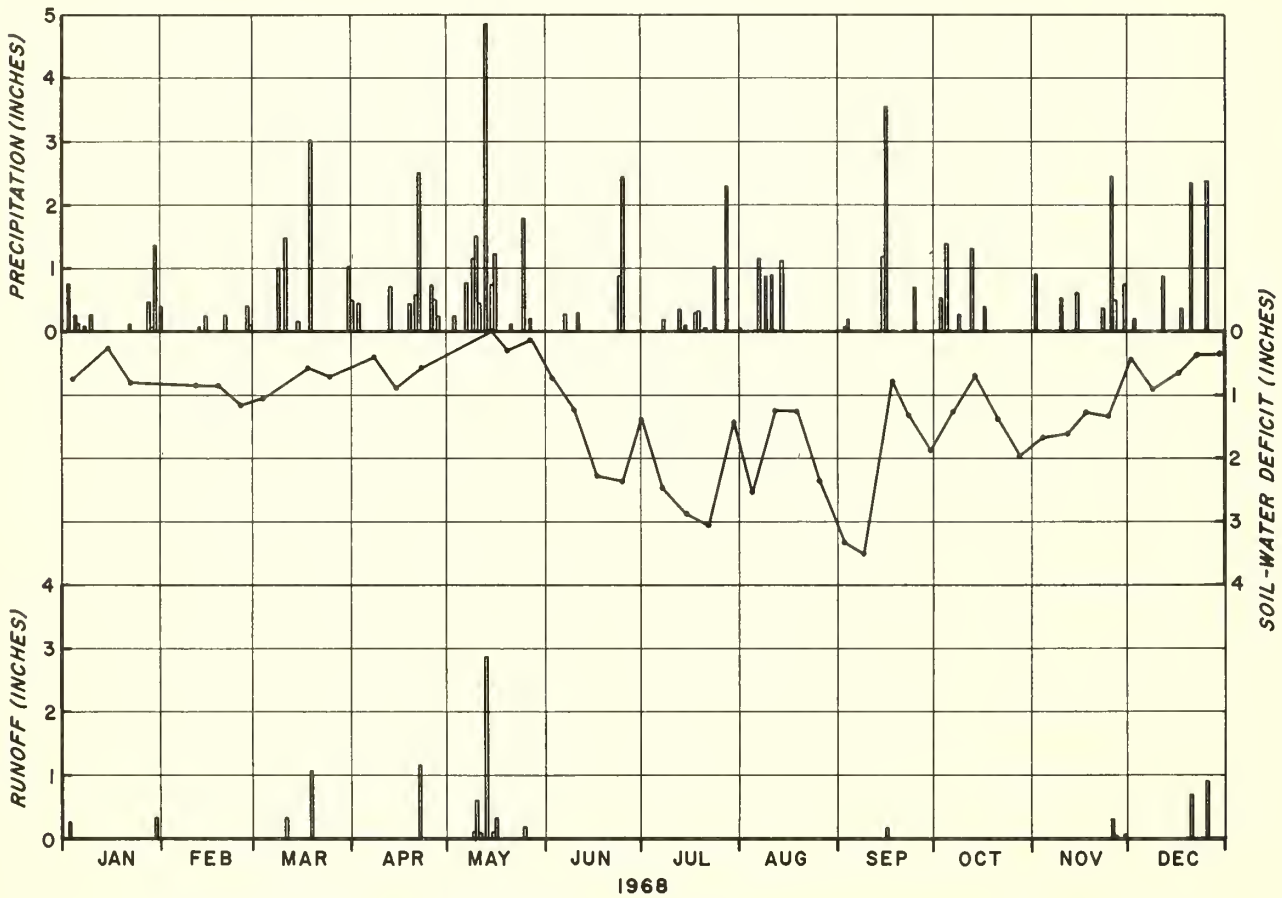

Figure 3.—*Precipitation, runoff, and deficits from maximum soil water for Alum Creek catchments, 1968.*

DISCUSSION

Between June and November, soil water levels were usually 2 to 3 inches less than maximum. As a result, runoff occurred during these months only from the largest storms. If streamflow in west-central Arkansas is to be increased, ways must be found to increase soil water levels during summer and early fall. Evapotranspiration losses from June through September were very high on the sample catchments. In fact, seasonal changes in evapotranspiration rather than in rainfall appear to be the major cause of low soil water levels and limited runoff in summer and fall. Evapotranspiration can be reduced by removing part of the vegetation from a watershed. On the study catchments, the timber stands will be lightly and heavily thinned and the effects of these treatments on soil water, runoff, and sediment production will be observed.

LITERATURE CITED

1. Blocker, W., and Bower, D.
   1963. Filter for sampling sediment in small streams. J. Soil and Water Conserv. 18: 222.

2. Lawson, E. R.
   1967. Throughfall and stemflow in a pine-hardwood stand in the Ouachita Mountains of Arkansas. Water Resour. Res. 3: 731-735.

3. Thornthwaite, C. W., and Mather, J. R.
   1957. Instructions and tables for computing potential evapotranspiration and the water balance. Publications in climatology 10(3), 311 p. Centerton, N. J.: Drexel Inst. Technol.

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CUBIC-FOOT VOLUME TABLE AND POINT-SAMPLING FACTORS FOR WHITE PINE PLANTATIONS IN THE SOUTHERN APPALACHIANS

Glendon W. Smalley [1] **and Donald E. Beck** [2]

SOUTHERN FOREST EXPERIMENT STATION

Volume in cubic feet of the entire stem, outside bark, was derived from $V = 0.0026345(D^2H) + 0.11798$. *This equation was developed by weighted least squares from observations on 243 trees. A table of volumes per square foot of basal area is provided.*

The tables and equations published here apply to white pines *(Pinus strobus* L.) planted on abandoned fields in the southern Appalachians. They supplement merchantable volume tables published previously by the Southeastern Forest Experiment Station,[3] and were derived from the same set of 243 sample trees. Diameters at breast height ranged from 3.7 to 14.9 inches, outside bark (o.b.); total heights ranged from 20.5 to 93.0 feet.

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[2] Principal Silviculturist, Southeastern Forest Experiment Station, Asheville, N. C.

[3] Vimmerstedt, J. P. Cubic-foot volume tables for southern Appalachian white pine plantations. USDA Forest Serv. Southeast. Forest Exp. Sta. Res. Notes 162, 2 p. 1961.

Volume between the stump and a 3.0-inch top (o.b.) was derived graphically from taper curves. The portion above a 3.0-inch o.b. top was treated as a cone and the stump treated as a cylinder.

The volume equation is of the form

$$V = b_0 + b_1 (D^2H)$$

where V = gross volume, o.b., of entire stem in cubic feet

D = diameter at breast height, o.b., in inches

H = total height in feet

b_0, b_1 = regression constants.

The equation was developed by a weighted least-squares approach in which $(D^2H)^{-2}$ was the weight for each set of observations (tree).

Table 1 gives volumes for selected combinations of diameter and total height. The equation and the root mean square residual are shown below the table.

Table 2 gives the point-sampling factor for each combination of tree diameter and height

Table 1.—*Outside-bark volume of entire stem* [1]

D.b.h., o.b. (inches)	Total height in feet															
	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
	Cubic feet															
4	0.96	1.17	1.38	1.59	1.80	2.01	2.23	2.44								
5	1.44	1.76	2.09	2.42	2.75	3.08	3.41	3.74	4.07							
6	2.01	2.49	2.96	3.44	3.91	4.39	4.86	5.33	5.81	6.28	6.76					
7	2.70	3.35	3.99	4.64	5.28	5.93	6.57	7.22	7.86	8.51	9.15	9.80	10.45			
8			5.18	6.02	6.86	7.71	8.55	9.39	10.23	11.08	11.92	12.76	13.61	14.45		
9				7.59	8.65	9.72	10.79	11.85	12.92	13.99	15.06	16.12	17.19	18.26		
10					10.66	11.97	13.29	14.61	15.92	17.24	18.56	19.88	21.19	22.51	23.83	25.15
11						14.46	16.06	17.65	19.24	20.84	22.43	24.03	25.62	27.21	28.81	30.40
12								20.98	22.88	24.78	26.67	28.57	30.47	32.36	34.26	36.16
13											31.28	33.51	35.74	37.96	40.19	42.41
14													41.43	44.01	46.59	49.17

[1] Derived from $V = 0.0026345(D^2H) + 0.11798$.
Root mean square residual based on weighted regression coefficients + 0.16341 cu. ft.

appearing in the volume table. Volume per square foot of basal area was derived by dividing the volume equation by $0.005454D^2$, a formula for basal area.

In the tables, midpoints of the total height classes are multiples of 5 feet, e.g., 40 = 38 through 42 feet. The midpoint of each diameter class is given, e.g., 8 = 7.6 through 8.5 inches. The boxed portion of the tables indicates the extent of basic data. When maximum precision and accuracy are desired, volumes should be computed from the equations rather than read from the tables.

Table 2.—*Outside-bark volume of entire stem per square foot of basal area* [1]

D.b.h., o.b. (inches)	Total height in feet															
	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
	Cubic feet															
4	11.0	13.4	15.8	18.3	20.7	23.1	25.5	27.9								
5	10.5	12.9	15.4	17.8	20.2	22.6	25.0	27.4	29.8							
6	10.3	12.7	15.1	17.5	19.9	22.3	24.8	27.2	29.6	32.0	34.4					
7	10.1	12.5	14.9	17.3	19.8	22.2	24.6	27.0	29.4	31.8	34.3	36.7	39.1			
8			14.8	17.2	19.7	22.1	24.5	26.9	29.3	31.7	34.2	36.6	39.0	41.4		
9				17.2	19.6	22.0	24.4	26.8	29.2	31.7	34.1	36.5	38.9	41.3		
10					19.5	22.0	24.4	26.8	29.2	31.6	34.0	36.4	38.9	41.3	43.7	46.1
11						21.9	24.3	26.7	29.1	31.6	34.0	36.4	38.8	41.2	43.7	46.1
12								26.7	29.1	31.5	34.0	36.4	38.8	41.2	43.6	46.0
13											33.9	36.4	38.8	41.2	43.6	46.0
14													38.8	41.2	43.6	46.0

[1] Derived from $V/B.A. = 0.4830(H) + 21.6318/D^2$

SOUTHERN FOREST EXPERIMENT STATION

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TEXAS "LOST PINES" NOT SUPERIOR ON DRY SITES IN NORTHERN MISSISSIPPI

B. P. Dickerson [1]

SOUTHERN FOREST EXPERIMENT STATION

"Lost Pines" from two Texas sources failed to surpass loblolly pines from Mississippi and Alabama in survival or growth when planted for 3 successive years on drouthy sites in northern Mississippi.

Loblolly pine *(Pinus taeda* L.), the tree species most often planted for soil stabilization on the Southern Coastal Plains, survives and grows well on typical eroded sites, but mortality is often excessive on drouthy sites, such as deep sands and cemented Coastal Plain subsoils. Reported here are trials on such sites of "Lost Pines," a strain of loblolly pine from southeastern Texas.

Lost Pines grow 100 miles west of what is considered the commercial range of loblolly in an area of low rainfall and dry, often rocky soils. They were selected for study because of their proven drouth and heat resistance *(3)*.

[1] The author is Associate Silviculturist at the Forest Hydrology Laboratory which is maintained in Oxford, Miss., by the Southern Forest Experiment Station in cooperation with the University of Mississippi. The study described was done in cooperation with the Yazoo-Little Tallahatchie Flood Prevention Project.

METHODS

For the tests, seeds were obtained from four sources:

Franklin County in southwestern Mississippi—1960 general collection on Homochitto National Forest; a source commonly planted in northern Mississippi.

Talladega and Clay Counties in central Alabama—1963 general collection on Talladega National Forest; a frequent source for planting in northern Mississippi since 1954.

Bastrop and Fayette Counties, Texas—Seed lot 64 Drouth Resistant-Progeny Tested;[2] seed from selected parent trees on the seed orchard of the Arthur Temple, Sr., Research Area.

Bastrop and Fayette Counties, Texas—Seed lot 64 Drouth Hardy Untested;[2] a source randomly collected from nonprogeny-tested trees. It has been found that there is as much variation in drouth hardiness between individual trees within the Bastrop-Fayette

[2] Lot name and number assigned by Texas Forest Service.

area as there is between trees in the Bastrop-Fayette area and any other pine seed provenance in the pine-hardwood region of Texas.[3]

In Bastrop County, Texas, annual precipitation is about 68 percent of the averages for the study planting sites, and for the other sources of seed. Summer (June to August) rainfall in central Alabama and southwestern and northern Mississippi averaged about 4 inches more than in Texas. Average July and January temperatures were slightly higher at Bastrop County, Texas, than at any other seed source.

All seedlings were grown and handled under identical conditions at the Ashe Nursery, Brooklyn, Mississippi. Seedlings were lifted in late February of each year and refrigerated until outplanted. Prior to outplanting, seedlings were sorted and graded. Only grades 1 and 2 *(2)* of the seedlings from Mississippi and Alabama sources were retained. Because of short stem lengths many of the Lost Pines did not qualify as grade 2 seedlings; they were planted if all other requirements were met.

Seedlings from the Texas sources generally had shorter stems, larger diameters, and more numerous lateral roots than did seedlings from the other sources. These differences were more apparent in the 1966 and 1967 seedlings than in those planted in 1968.

Four examples of each of three planting sites —deep sand, Coastal Plain subsoil, and alluvium—were selected on or near the Tallahatchie Experimental Forest in Lafayette County, Mississippi. The four deep sands all had a trace of organic matter in the upper 6 inches. The Coastal Plain subsoils ranged in texture from plastic clay to sandy loam with a lens of gravel. The alluvial soils varied in internal drainage and texture.

Trees and shrubs were removed from all plots. Lesser vegetation was left except on the alluvial sites, where heavy accumulations of dead grass were burned to facilitate planting. Scattered remnants of topsoil were removed from the Coastal Plain subsoils to reduce variation within each planting location. This work was completed several months before the initial planting in March 1966.

[3] Personal communication from Mason C. Cloud, Head, Reforestation Section, Texas Forest Service, College Station, Tex., January 21, 1966.

At each planting location, 12 plots, each 12 by 22 feet, were installed and randomly assigned a seedling source and planting year. Beginning in 1966, seedlings from the four different sources were outplanted each March on a 2- by 2-foot spacing, 50 seedlings per plot, for 3 successive years. After the planting disturbance subsided, seedling heights were measured to the nearest 0.1 foot.

Survivors were counted and heights remeasured each November. The 1966 and 1967 plantings were observed for 3 successive years, and the 1968 planting for 2 years.

Statistical analyses at the 0.05 level of confidence were designed to determine whether Lost Pines were superior to other loblolly pines on the adverse sites—the subsoil and the deep sand. Accordingly, seedling losses to known causes unrelated to site were excluded from analyses. Survival data at the end of the second growing season and field growth for two growing seasons were analyzed.

RESULTS AND DISCUSSION

The Lost Pines failed to surpass loblolly pines from Mississippi and Alabama sources in either height or survival on any of the test sites. Thus, despite drouth resistance demonstrated in previous studies *(1,3)*, Lost Pines appear to offer no advantages over the commonly chosen seed sources for erosion control planting in northern Mississippi.

There was little numerical difference between total mortality and that attributed to adverse site conditions alone. Winter-kill was no problem regardless of seed source. Most seedling mortality occurred during the first growing season. Only on the sandy clay did seedling mortality of the first two plantings fail to level off after the first growing season. Here, despite increasing losses, source effects were not evident.

Average annual precipitation in 1966 was 8.82 inches below normal, with extended drouth conditions occurring in early spring. Survival percentages for all sources were decidedly lower for the 1966 planting than in the succeeding plantings when annual precipitation was near or above normal (table 1).

On the sandy clay and alluvium, seedlings from the Mississippi and Alabama sources outgrew the Lost Pines (table 2). The Texas

Table 1.—*Average second-year survival by site, year planted, and seed source. Seedling mortality from known causes unrelated to site is excluded*

Site and year planted	Source			
	Mississippi	Alabama	Texas Drouth Resistant	Texas Drouth Hardy
	Percent			
Sandy clay				
1966	58	56	67	67
1967	66	71	76	72
1968	72	80	78	70
All years	65	69	74	70
Sand				
1966	58	69	50	70
1967	84	92	92	86
1968	72	88	84	82
All years	71	83	76	79
Alluvial				
1966	97	90	95	93
1967	93	95	99	86
1968	94	97	97	97
All years	95	95	97	92

Table 2.—*Average change in height of seedlings after two growing seasons in the field*

Site and year planted	Source			
	Mississippi	Alabama	Texas Drouth Resistant	Texas Drouth Hardy
	Feet			
Sandy clay				
1966	0.8	0.8	0.8	0.6
1967	.8	.7	.7	.7
1968	.7	.7	.6	.5
All years	.8	.7	.7	.6
Sand				
1966	1.6	1.2	1.3	1.3
1967	1.1	1.6	1.5	1.2
1968	.8	.9	.9	1.0
All years	1.2	1.2	1.2	1.2
Alluvial				
1966	3.6	3.3	2.9	2.6
1967	2.2	2.8	2.9	2.2
1968	2.0	2.1	1.9	1.6
All years	2.6	2.7	2.6	2.1

Drouth Resistant trees grew significantly faster than did the Texas Drouth Hardy, but no differences were found between the Mississippi and Alabama sources. On the sandy sites, no differences due to seed source were detected.

On all sites average growth remained fairly uniform for the first two plantings then declined substantially for the 1968 planting, possibly due to the low rainfall in 1969. Total rainfall for July 1969 was only 0.79 inch, and the accumulated January-July monthly totals were 8 inches below normal. Rainfall during the second growing season of the 1966 and 1967 plantings was near normal.

Rabbit browsing was light on all sites, and no preference was shown for any of the four

sources tested. Damaged seedlings sprouted, and their growth did not appear to suffer greatly.

Tip moths *(Rhyacionia frustrana* (Comst.)) attacked seedlings on all sites. No pattern of attacks was apparent, and growth and survival were not adversely affected.

LITERATURE CITED

1. Thames, J. L.
   1962. Loblolly best but seed source important in erosion-control plantings in north Mississippi. USDA Forest Serv. Tree Planters' Notes 55: 21-22.

2. Wakeley, P. C.
   1954. Planting the southern pines. USDA Agr. Monogr. 18, 233 p.

3. Zobel, B. J., and Goddard, R. E.
   1955. Preliminary results on tests of drought hardy strains of loblolly pine *(Pinus taeda* L.). Tex. Forest Serv. Res. Note 14, 23 p.

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STAIN AND DECAY AROUND CARPENTERWORM GALLERIES IN SOUTHERN HARDWOOD TREES

J. D. Solomon [1] and E. R. Toole [2]

SOUTHERN FOREST EXPERIMENT STATION

The wood was discolored around all 60 carpenterworm galleries examined in six host trees. Stain spread more in Nuttall oak than in elms and green ash. Decay was visible around 12 of the 60 galleries, mostly in Nuttall oak. Stain fungi, particularly Fusarium *sp., were the most common organisms isolated from wood around the galleries. Bacteria were also common. Decay fungi* (Coprinus *sp. and* Polyporus *sp.) were isolated from only two trees that showed visible symptoms of decay.*

Most organisms that stain or decay wood in living trees require exposed sapwood to become established *(1)*. In the study described here, galleries of carpenterworms, *Prionoxystus robiniae* Peck, in three southern hardwood species were examined for stain, decay, and associated microorganisms.

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[2] Assistant Professor, Forest Prod. Utilization Lab., Mississippi State University, State College, Miss.

METHODS AND MATERIALS

Two trees each of Nuttall oak, *Quercus nuttallii* Palmer, green ash, *Fraxinus pennsylvanica* Marsh, and American elm, *Ulmus americana* L., ranging from 14 to 20 cm. in diameter 1.4 m. above the ground were selected for study. By a previously described method *(2)*, one tree of each species was artificially infested with newly hatched carpenterworms in June 1968 and another in June 1969. The young carpenterworms were hatched from eggs laid by field-reared moths. The trees were cut during March 1970, 10 and 22 months after infestation. The infested portions of the trees were ripped slightly to one side of the entrance holes on a bolter saw. Ten galleries from each of the six trees were sawn out intact on a bandsaw and the full length exposed with wood chisels (fig. 1).

Carpenterworms typically bore more or less horizontally into the stem, then extend their galleries upward (fig. 1). Each gallery was arbitrarily divided into a horizontal or lower

Figure 1.—*Stained wood around typical carpenterworm gallery.*

section and a vertical or upper section. Vertical and horizontal spread of both stain and visible decay were measured in the horizontal part of the gallery. Stain and decay were differentiated by color and texture of the affected wood.

To isolate associated organisms, six sample chips (three from the horizontal section and three from the vertical section) were taken from the wood around each of 10 galleries in each of the six trees. The chips were identified and cultured individually at 25° C. for 2 weeks in diffuse daylight on malt agar [3] tube slants. The microbial growth from the chips was examined and classified. Fungi were identified by genus and classed as causers of stain, mold, or decay, based upon their appearance in culture and a knowledge of their activity. A few fungi that failed to produce spores remain unidentified. Bacteria were placed in a single group.

[3] Malt agar prepared by adding 20 g. malt extract and 20 g. agar to 1,000 ml. distilled water.

RESULTS AND DISCUSSION

Stain: Stained wood was present around all galleries (fig. 1). Discolorations ranged from light gray to dark brown or black and extended about the same distance above and below the gallery.

Stain was most extensive in Nuttall oak and least in green ash (table 1). Stain had spread further around 22-month-old galleries than around those 10 months old. Horizontal spread was minimal for all three species. It averaged about one-tenth of the vertical spread.

Decay: Decay was much less prevalent and extensive than stain (table 1). The wood around all 22-month-old galleries in Nuttall oak had visible decay, while only one 10-month-old gallery exhibited decay. The mean vertical extent of decay around the older galleries was about one-fourth that of stain. Horizontal spread of decay was approximately one-half that of the stain. In green ash, decay was evident in only one gallery. No visible decay was found in elm.

Microorganisms: Fungi and bacteria were isolated from wood around most galleries (table 2). *Fusaria* were prevalent in all three tree species but were isolated most frequently from galleries in elms. In five of the six trees *Fusaria* were isolated more commonly in the lower or horizontal portion of the gallery than in the vertical part. *Ceratocystis* was common in 22-month-old galleries, but was found in only one 10-month-old gallery. Several nonstain fungi, including *Aspergillus, Penicillium, Cephalosporium, Trichoderma,* and one unidentified fungus, were isolated occasionally.

Two genera of decay fungi were identified. *Polyporus* was found only in 22-month-old galleries in Nuttall oak. *Coprinus* occurred in the same tree and was also isolated from two 10-month-old galleries in green ash. No decay fungi were isolated from galleries in elm.

Bacteria, the second most common group of organisms associated with galleries (table 2), were isolated with about equal frequency from the upper and lower portions of the galleries in all host species. Isolates from the vertical part of the galleries were more often sterile than those from the horizontal, likely because the vertical part of the gallery was drier and it was the newest portion which had less time

Table 1.—*Spread of stain and decay around carpenterworm galleries in living trees of three species*

Age of galleries, and tree species	Vertical spread				Horizontal spread			
	Stain		Decay		Stain		Decay	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
	Millimeter							
10 months								
Nuttall oak	100.4a [1]	32-200	[2] 5.0	0-50	9.6a	2-20	[2] 0.8	0-8
American elm	92.6a	64-130	0	0	3.4b	1-4	0	0
Green ash	23.6b	16-44	[2] 4.0	0-40	2.2b	2-4	[2] 0.2	0-2
22 months								
Nuttall oak	163.8a	88-280	43.2	4-80	10.0a	4-18	4.6	2-12
American elm	97.2b	70-132	0	0	4.2b	2-8	0	0
Green ash	42.2c	20-50	0	0	3.4b	2-6	0	0

[1] Within a column and age group, means followed by the same letter do not differ significantly at the 0.01 level.

[2] Mean computed from decay in only one gallery.

Table 2.—*Frequency of isolation of microorganisms from wood samples taken around carpenterworm galleries* [1]

Microorganism	Nuttall oak				Elm species				Green ash			
	10 months		22 months		10 months		22 months		10 months		22 months	
	Hor.[2]	Vert.[3]	Hor.	Vert.	Hor.	Vert.	Hor.	Vert.	Hor.	Vert.	Hor.	Vert.
	Percent											
Stain fungi												
Fusarium	67	40	27	13	47	50	80	50	60	3	77	23
Ceratocystis	0	0	13	7	0	0	3	7	3	0	23	27
Other	10	3	0	3	0	0	0	0	10	7	0	3
Mold fungi												
Aspergillus	7	0	0	0	13	0	3	0	0	0	0	0
Penicillium	0	10	0	0	0	0	0	0	0	0	0	3
Cephalosporium	3	0	0	0	0	0	3	0	0	0	0	0
Trichoderma	23	0	0	3	13	3	0	0	3	0	0	0
Other	0	3	0	0	0	0	0	0	0	7	0	0
Decay fungi												
Coprinus	0	0	40	23	0	0	0	0	0	7	0	0
Polyporus	0	0	17	27	0	0	0	0	0	0	0	0
Bacteria	23	30	3	7	23	37	40	50	40	37	7	37
Sterile	7	23	3	17	17	17	3	13	10	43	0	30

[1] Each number is percent of isolation in 30 samples. Columns may total over 100% because of the occurrence of more than one organism in some samples.

[2] Hor. is the horizontal or lower portion of the gallery.

[3] Vert. is the vertical or upper portion of the gallery.

to become infected. Usually only one organism was isolated from a sample chip but occasionally both bacteria and a fungus were isolated from the same chip.

A succession of microorganisms has been shown to occur in wood during staining and decay *(1)*. In some cases, decay fungi appear to invade only those tissues that have been previously invaded by bacteria and/or certain stain fungi. This phenomenon appeared to occur in the present study in which stain fungi and bacteria were isolated from all the galleries, while decay fungi had invaded galleries in only two of the six trees and had extended only about half the distance of the stain.

Carpenterworm galleries penetrate the bark, sapwood, and sometimes the heartwood and may remain open for 1 to 3 years. Based on the results of the present study, it appears that these galleries can be important entryways for stain and decay organisms.

LITERATURE CITED

1. Shigo, A. L.
   1967. Successions of organisms in discoloration and decay of wood. *In* Int. Rev. For. Res. II, p. 237-299. New York: Acad. Press.

2. Solomon, J. D.
   1967. Rearing the carpenterworm, *Prionoxystus robiniae,* in the forest (Lepidoptera: Cossidae). Ann. Ent. Soc. Am. 60: 283-285.

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SITE INDEX CURVES FOR RED AND WHITE OAKS IN THE BOSTON MOUNTAINS OF ARKANSAS

David L. Graney and David R. Bower [1]

SOUTHERN FOREST EXPERIMENT STATION

Site index curves for white oak and red oaks (northern red and black oaks) derived from stem analysis data collected in the Boston Mountains of northern Arkansas differ from each other and from previously published upland oak curves.

Harmonized site index curves developed for the entire commercial range of oak *(6)* have long been the standard reference for estimating site index of both red and white oak stands in the Boston Mountains of northern Arkansas, despite the demonstrated superiority of locally derived curves for northern red oak in the Lake States *(2)* and for oak in the Southeast *(5)*. This note presents two sets of curves for the Boston Mountains, one for white oak *(Quercus alba* L.), and one for red oaks—northern red oak *(Q. rubra* L.) and black oak *(Q. velutina* Lam.).

METHODS

Standard methods of stem analysis and computation *(1,3,4,7)* were followed in constructing the curves. Stems of 278 dominant and codominant trees were analyzed; 136 were white oak and 142 were red or black oak. Each oak group was represented by a wide range of site indexes, and stand ages ranged from 50 to 108 (tables 1 and 2). All sectioned trees were located in even-aged, well-stocked stands that contained no evidence of cutting, grazing, or severe burning.

Each tree was sectioned at 0.5 foot, at 4.5 feet, and at intervals of 4 to 12 feet up to the growing tip of the tree.[2] Total height was recorded for each tree, and annual rings were counted at each of the sectioned points.

The ring counts at the cross-sections were converted to tree ages at these points. Heights and ages were then plotted for individual trees and inspected for indications of early suppression or top breakage. Trees showing any such evidence were rejected. Individual tree curves for northern red oak and black oak were similar, and the decision was made to derive a single set of curves for pooled red and black oak data.

Data for the two species groups (white and red oaks) were then stratified by 10-foot site

[1] The authors are Associate Silviculturist stationed in Fayetteville, Ark., and Mathematical Statistician stationed in New Orleans, Southern Forest Experiment Station, USDA Forest Service, at the time the research was initiated. Bower is now Forest Biometrician at the Weyerhaeuser Research Center, Centralia, Wash.

[2] Some 8- and 12-foot saw logs were cut from 16 white oak and 22 red and black oak sample trees.

index classes (at age 50). Each 10-foot site index class was represented by a minimum of 18 sample trees. The fewest observations were recorded for the highest and lowest site classes in each species group (tables 1 and 2). Age distribution varied widely for most site index classes, but the majority of sample trees were between 50 and 59 years old. The relatively few sample trees older than 70 years were fairly evenly distributed among site index classes.

Table 1.—*Distribution of sample white oaks by age and site index classes*

Total age (years)	Site index class				Total
	35-44	45-54	55-64	65-74	
	Number of trees				
50-59	5	37	23	12	77
60-69	9	14	9	4	36
70-79	2	2	2	2	8
80-89	2	3	4	2	11
90-99		1	1	1	3
100+		1			
Total	18	58	39	21	136

Table 2.—*Distribution of sample red oaks*[1] *by age and site index classes*

Total age (years)	Site index class				Total
	45-54	55-64	65-74	75-84	
	Number of trees				
50-59	19	43	20	14	96
60-69	2	4	2	2	10
70-79	2	3	4	4	13
80-89	2	2	3	2	9
90-99	1	2	2	2	7
100+	2	3	2		7
Total	28	57	33	24	142

[1] Includes both northern red oak and black oak.

The individual height/age curves were next combined to form one average height/age curve for each 10-foot site index class. These composite curves were fairly uniform and indicated no obvious polymorphic tendencies.

Growth patterns in second-growth stands were not sigmoid. Instead, initial growth rates were rapid and did not slow for 30 to 40 years. This pattern is probably characteristic of trees developing from seedling sprouts rather than from true seedlings.

EQUATIONS

Various mathematical models were tested for expressing the observed height/age relationship. Logarithmic functions such as log height = a + b (1/age) produced curves that were too flat. Curves based on the relationship height = $\sqrt{\text{age}}$ adequately represented height growth beyond age 50 but over-estimated height at younger ages. The relationship height = $(\text{age})^{0.75}$ produced curves that were adequate for younger trees but overestimated heights beyond age 50.

The conditioned polynomial, height = $b_1 (\text{age})^{-2} + b_2 (\text{age})^{-1} + b_3 (\text{age})^{-0.5} + b_4 (\text{age})^{0.5} b_5 (\text{age}) + b_6 (\text{age})^2$, was fitted stepwise to all stem analysis data for each species, with the following satisfactory results:

Red oaks

$$\text{Height} = 1.60443 (\text{age}) - 0.00759 (\text{age})^2 + 0.45558 (\text{age})^{0.5} \quad R^2 = 0.98$$

White oak

$$\text{Height} = 1.24692 (\text{age}) - 0.00543 (\text{age})^2 + 0.77468 (\text{age})^{0.5} \quad R^2 = 0.98$$

Inserting the condition that height at age 50 is site index (SI) and solving for height in terms of site index and age provided equations for generating the site index curves (figs. 1 and 2):

Red oaks

$$\text{Height} = 0.02 (\text{SI}) (\text{age}) + 0.31507 (\text{age}) - 0.00759 (\text{age})^2 + 0.45558 (\text{age})^{0.5}$$

White oak

$$\text{Height} = 0.02 (\text{SI}) (\text{age}) + 0.1619 (\text{age}) - 0.00543 (\text{age})^2 + 0.77468 (\text{age})^{0.5}$$

The two sets of curves derived from these models fit the observed data very closely for all ages and sites.

Growth patterns for white oak and red oaks were essentially similar up to about age 50, with white oak growing slightly slower than the red oaks. Thereafter, however, white oak maintained a relatively rapid growth rate up to and beyond 80 years of age. Red oak height growth declined sooner and more rapidly. For example, if red oak and white oak are the same height at age 50, the white oak is likely to be

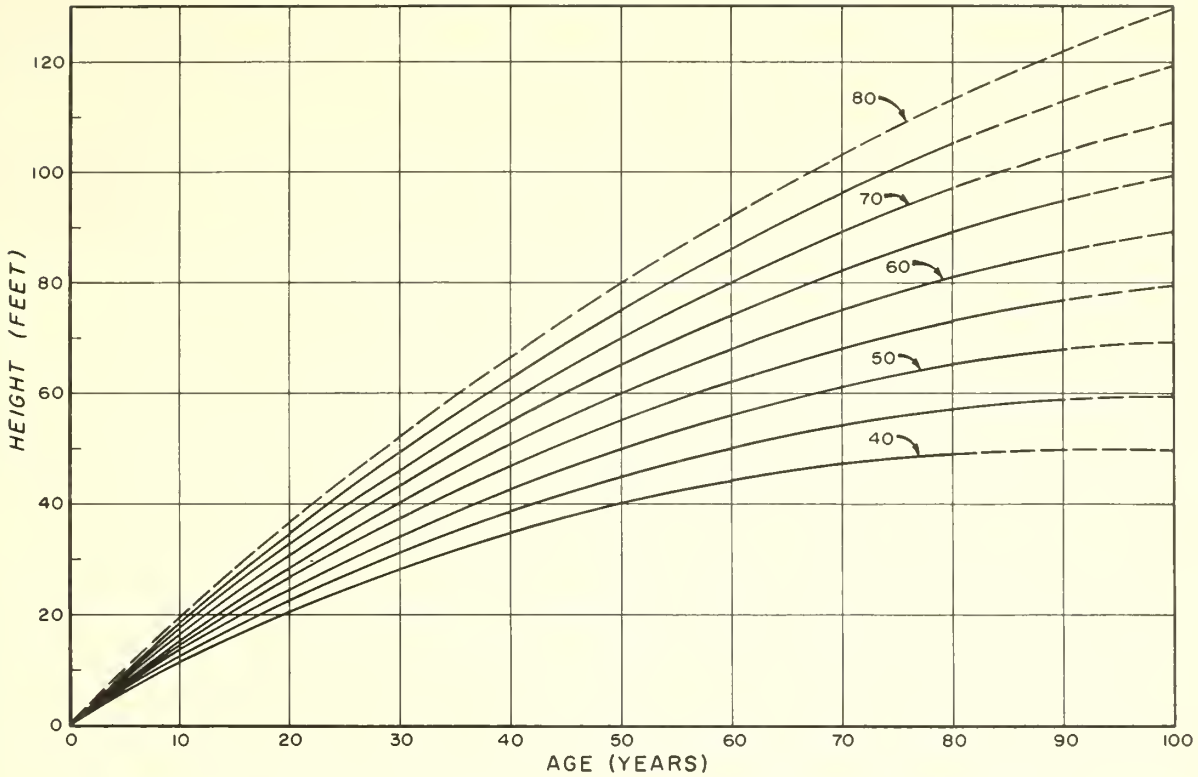

Figure 1.—*White oak site index curves for the Boston Mountains. Dashed lines indicate extrapolation.*

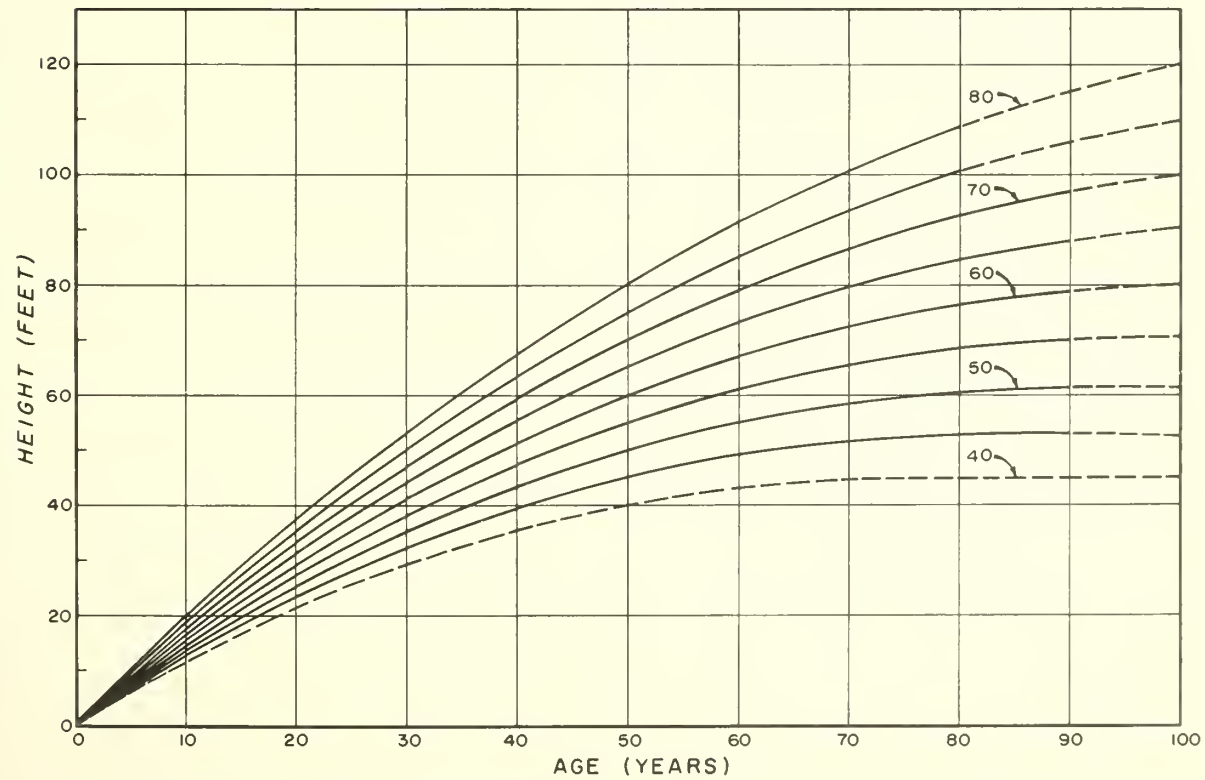

Figure 2.—*Red oak site index curves for the Boston Mountains. Dashed lines indicate extrapolation.*

nearly 5 feet taller at age 80 and may be as much as 10 feet taller than red oak at age 100.

The curves for red oaks and white oak agree fairly closely with Schnur's *(6)* upland oak curves in early years, especially on the medium sites (figs. 3 and 4). On poor sites, early growth is somewhat more rapid than predicted by the old curves; on good sites the opposite is true. After age 50, white oak on poor sites grows about as shown in the upland oak curves, but on better sites the new and old curves differ considerably. At 80 years on a site with an index of 70, white oak is likely to be 10 feet taller than indicated by Schnur's curves.

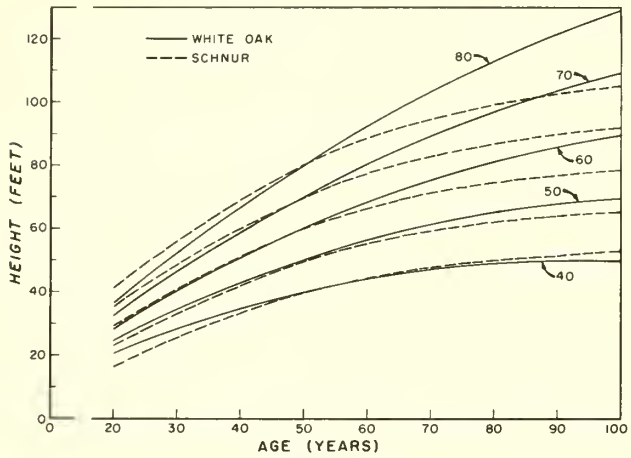

Figure 3.—*White oak curves for Boston Mountains compared with Schnur's curves* (6).

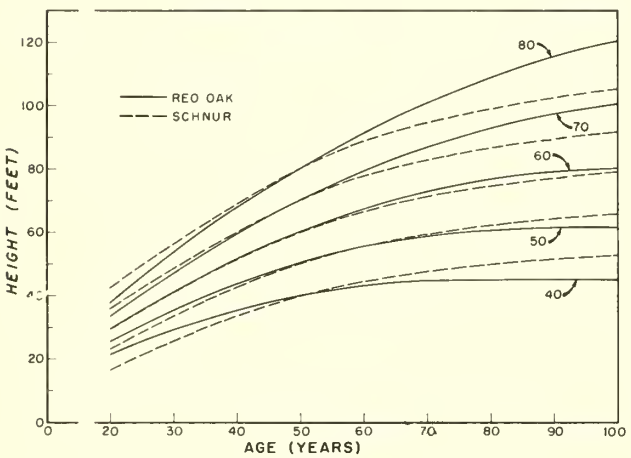

Figure 4.—*Red oak curves for the Boston Mountains compared with Schnur's curves* (6).

The differences in growth patterns between the new and old curves are sufficient to recommend the locally derived curves for determining site index of both red and white oaks in the Boston Mountains of northern Arkansas.

LITERATURE CITED

1. Curtis, R. O.
   1964. A stem-analysis approach to site index curves. Forest Sci. 10: 241-256.
2. Gevorkiantz, S. R.
   1957. Site index curves for red oak in the Lake States. USDA Forest Serv. Lake States Forest Exp. Stn. Tech. Note 485, 2 p.
3. Hegar, L.
   1968. A method of constructing site-index curves from stem analyses. Forest. Chron. 44(4): 11-15.
4. Johnson, F. A., and Worthington, N. P.
   1963. Procedure for developing a site index estimating system from stem analysis data. USDA Forest Serv. Res. Pap. PNW-7, 10 p. Pacific Northwest Forest and Range Exp. Stn., Portland, Oreg.
5. Olson, D. J., Jr.
   1959. Site index curves for upland oak in the Southeast. USDA Forest Serv. Southeast. Forest Exp. Stn. Res. Note 125, 2 p.
6. Schnur, G. L.
   1937. Yield, stand, and volume tables for even-aged upland oak forests. USDA Tech. Bull. 560, 87 p.
7. Stage, A. R.
   1963. A mathematical approach to polymorphic site index curves for grand fir. Forest Sci. 9: 167-180.

SOUTHERN FOREST EXPERIMENT STATION

1971

U.S. FOREST SERVICE RESEARCH NOTE

SO-122

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

LOBLOLLY PINE SEEDLINGS RESPOND TO FOLIAR NITROGEN FERTILIZATION

Paul D. Duffy [1]

SOUTHERN FOREST EXPERIMENT STATION

Potted loblolly pines (Pinus taeda *L.) grew faster in height and dry weight after heavy than after light foliar applications of ammonium nitrate or urea. Ammonium nitrate caused greater increases in foliage weight than did urea.*

Rapid initial growth is so important in erosion-control plantings that cultural techniques not ordinarily used in forest plantations should be considered. In watershed stabilization research at Oxford, Mississippi, we are exploring the possibilities of numerous planting and cultural techniques, including foliar fertilization, which has proved effective on some crop plants *(1,3)*. Reported in this note are positive responses to foliar fertilization of loblolly pine *(Pinus taeda* L.) seedlings with nitrogen.

In previous studies, mixed results have been obtained from application of fertilizers to the needles of southern pines. Height growth of phosphorus-deficient loblolly pine seedlings was improved by applying diammonium phosphate to the foliage *(4)*. Dipping slash pine *(P. elliottii* Engelm.) seedlings in the same fertilizer did not influence performance after planting *(5)*, and growth of longleaf pine *(P. palustris* Mill.) seedlings was not improved by spraying their foliage with a urea compound *(6,* p. 42). In the present study, two forms of nitrogen, two amounts, and two spraying regimes were tested.

[1] The author is Associate Soil Scientist at the Forest Hydrology Laboratory, maintained by the South. Forest Exp. Stn., USDA Forest Service, at Oxford, Miss., in cooperation with the Univ. of Mississippi.

PROCEDURES

In April, 120 1-year-old loblolly pine seedlings were planted in individual perlite-filled pots 5½ inches in diameter and 6 inches deep. The pots were placed in a greenhouse and supplied with abundant water but no fertilizer until early July. Then 0.64 g. superphosphate and 0.21 g. muriate of potash, mixed in water, were added to each pot to approximate an application of 75 pounds per acre each of P_2O_5 and K_2O based on the pot's surface area.

Nitrogen fertilization, which was delayed to permit development of more foliage surface for spray retention than was available at planting time, was begun on July 14. Nitrogen in the required form and amount (table 1) was mixed with 50 cc. of water and either poured on the soil (perlite) surface or sprayed on the foliage.

Table 1.—*Treatments and heights of seedlings at time of fertilization*

Treatment number	Application		Nitrogen fertilizer	Amount of fertilizer	Nitrogen level	Mean seedling height when fertilized
	Method	Frequency				
				Gram/seedling		*Cm.*
1	Soil	1	Ammonium nitrate	0.77	Low	28.7
2	Soil	1	Urea	.55	Low	24.9
3	Foliar	1	Ammonium nitrate	.77	Low	28.2
4	Foliar	1	Urea	.55	Low	28.5
5	Foliar	1	Ammonium nitrate	1.53	High	27.1
6	Foliar	1	Urea	1.10	High	26.3
7	Foliar	5	Ammonium nitrate	.77	Low	25.8
8	Foliar	5	Urea	.55	Low	25.9
9	Foliar	5	Ammonium nitrate	1.53	High	26.9
10	Foliar	5	Urea	1.10	High	24.5

Nitrogen was added in separate treatments as commercial ammonium nitrate fertilizer and National Formulary grade urea. Both are readily soluble in water and easily applied to the foliage. Ammonium nitrate had stimulated growth of loblolly pine in a local study *(2)*, and foliar applications of urea have stimulated growth of other species *(1,3)*. The lower of the two nitrogen levels tested (table 1) resulted in the best combination of pine growth and survival when applied to soil in an earlier pot study; the higher level produced greater growth but less survival in the same study *(2)*. The low level is approximately 150 pounds of nitrogen per acre; the high level, 300 pounds of nitrogen per acre. One-half of the foliar-fertilized seedlings were sprayed once. The others, which were sprayed five times at weekly intervals, received the same total nitrogen as did those sprayed once.

Since one study objective was to compare foliar with soil application, plastic covers were placed over the pot surface during spraying to keep spray or drip from the soil surface. Seedlings were carefully watered after fertilization to prevent the washing of nitrogen salts from their foliage. Tests showed that seedlings retained about 25 cc. or 50 percent of the sprayed nitrogen solution.

Survival and heights were recorded in November, then foliage was clipped, dried at 70° C., weighed, and analyzed for nitrogen. Only current-season foliage was clipped, since needles grow only in their initial season and no response to fertilization by older needles was expected.

A completely randomized plot design was used with three plots, each composed of four seedlings per treatment. Variances in survival and in height growth and foliage weight of surviving seedlings were analyzed with orthogonal comparisons. Treatment means were compared with Duncan's new multiple range test at the 0.01 level. The eight foliar treatments were analyzed as a $2\times2\times2$ factorial with nitrogen form, level, and frequency of application as factors.

RESULTS AND DISCUSSION

Seedlings receiving the high level of nitrogen on their foliage grew significantly more in height after fertilization and produced significantly heavier foliage than seedlings fer-

Table 2.—*Treatment effects on height growth, weight of new foliage, and nitrogen content of new foliage at the end of one growing season*

Treatment level, place applied, and frequency	Post-treatment height growth		Foliage weight		Foliar nitrogen	
	Ammonium nitrate	Urea	Ammonium nitrate	Urea	Ammonium nitrate	Urea
	– – *Cm.* – –		– – – *G.* – – –		– *Percent* –	
Low level on foliage						
1	3.7	4.6	4.33	2.40	0.73	0.77
5	3.4	4.1	4.10	3.26	1.17	.70
High level on foliage						
1	12.1	8.1	6.67	3.93	.85	.85
5	8.4	9.2	5.20	4.86	.97	.83
Low level on soil						
1	14.5	4.7	9.53	5.10	1.04	.93

tilized at the low level (table 2). Nitrogen concentrations in clipped needles ranged from 0.70 to 1.17 percent. They were greater in seedlings that received the high than the low level of foliar fertilizer, except when ammonium nitrate was sprayed five times. Seedlings foliar-fertilized with ammonium nitrate produced significantly more foliage weight than did those foliar-fertilized with urea (table 2).

Survival among foliar-fertilized seedlings ranged from 25 to 100 percent but was not significantly related to level, form, or frequency of nitrogen applications. Fifteen of the 96 seedlings whose needles were sprayed died within 1 month of treatment and 39 died within 4 months. Seven of 12 seedlings sprayed once with the high level of urea began turning brown within 5 days. Only three of the 12 survived.

In comparing the results of soil and foliar treatments, it must be remembered that about half of the material sprayed onto needles was lost. The most valid comparisons are between the low level soil application and high levels of foliar application, since about the same amount of nitrogen was delivered to seedlings in both treatments. The best response to foliar application was 12.1 cm. in height growth and 6.67 g. in foliage weight produced by the high level of ammonium nitrate. Survival after this treatment was 75 percent. Fertilizing the soil with the low level of ammonium nitrate produced 14.5 cm. of height growth and 9.53 g. of foliage weight; survival was 100 percent. Foliage weights differed significantly between these two treatments. In terms of height growth and survival, effectiveness of the two treatments did not differ significantly.

Since the seedlings responded favorably to foliar application of nitrogen and since soil treatments were not clearly superior to foliar treatments, further study is being planned of effects of applying nitrogen to needles of loblolly pine planted for erosion control.

LITERATURE CITED

1. Boynton, D.
   1954. Nutrition by foliar application. Annu. Rev. Plant Physiol. 5: 31-54.

2. Duffy, P. D.
   1967. Fertilizing with nitrogen and phosphorus increases loblolly pine foliage production. J. Miss. Acad. Sci. 13: 21-23.

3. Mukherjee, S. K., De, R., and Saxena, P. N.
   1966. Efficiency of utilization of soil- and foliar-applied nitrogen and phosphorus as revealed by tuber production and nutrient uptake of potatoes. Soil Sci. 102: 278-283.

4. Schopmeyer, C. S.
   1961. Foliar absorption and translocation of phosphorus by loblolly pine seedlings. Forest Sci. 7: 330-336.

5. Schultz, R. P.
   1968. Soil or foliar fertilization of well-

drained and flooded slash pine seedlings. USDA Forest Serv. Res. Pap. SE-32, 8 p. Southeast. Forest Exp. Stn., Asheville, N. C.

6. Southern forest Experiment Station. 1953. 1952 annual report. USDA Forest Serv. South. Forest Exp. Stn., 116 p.

SOUTHERN FOREST EXPERIMENT STATION

1971

U.S. FOREST SERVICE RESEARCH NOTE

SO-123

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

GROWTH OF PLANTED LOBLOLLY PINE AFTER ROW AND SELECTIVE THINNING

Charles X Grano

SOUTHERN FOREST EXPERIMENT STATION

A combination of row and selective thinning was practical and cubic yields were similar to those from selective thinning in a loblolly pine plantation in southern Arkansas. Removing alternate rows in two cuts resulted in smaller tree diameters than selective thinning.

With the cost of woods labor rising rapidly, row thinning, which lends itself readily to mechanization, is certain to become increasingly popular. How will row thinning affect stand yields and the development of crop trees? In 1955 the Georgia-Pacific Corporation and the U. S. Forest Service established a study near Crossett, Arkansas, to answer this question.

METHODS

A 14-year-old loblolly pine *(Pinus taeda* L.) plantation on Leshe silt loam soil was selected for the study. Site index was calculated to be 105 feet at age 50, a high value for loblolly pine. Trees had been planted at 6-foot intervals in rows spaced 5 feet apart. Before treatment the stand contained 1,256 trees per acre in trees 2 inches d.b.h. and larger, and 1,631 cubic feet (21.5 cords) of wood. Trees 4 inches and larger accounted for 146 square feet of basal area per acre.

Three ¼-acre plots were randomly assigned to each of four treatments:

Two rows removed.

Every fourth row was removed in the first thinning. In the second, the middle row of the residual 3-row strip was cut. The third and subsequent thinnings were selective, favoring desirable dominants and codominants. In the second and all subsequent thinnings the stand was cut back to 97 square feet of basal area per acre.

One row removed.

Every fourth row was removed in the first thinning. The remaining rows were lightly thinned, favoring desirable dominants and codominants. All other thinnings were selective, reducing the stand to 85 square feet per acre at each cut.

Light selection.

All thinnings were selective, leaving at each cut a basal area equal to that where two rows were removed.

Moderate selection.

All thinnings were selective leaving approximately 85 square feet of basal area.

On each plot, 25 crop trees were selected, numbered, and favored throughout the study. Crop trees were pruned to a height of 17 feet in 1955. Other trees were left unpruned. Thinnings were made every 3 years. Diameter, merchantable and total height, bark thickness, and form class were measured at these times. Volume tables based on form class changes were prepared for each measurement period.

RESULTS

The amount of water available during the growing season was average to plentiful during most of the 15-year study. Water was in very short supply for 3 years, about average for 5 years, and quite plentiful for 7 years.

Selective thinning to 97 square feet of basal area resulted in significantly [1] greater cubic growth than other treatments. Cubic growth percent was greater on plots that were row thinned once than on those row thinned twice or lightly thinned selectively. It was higher after moderate selective thinning than after two row thinnings (table 1).

Periodic annual cubic growth and cubic growth percent were excellent after all treatments. Tree form class increased from 65 in 1955 to 81 in 1969. Regardless of treatment, periodic annual cubic growth was decidedly greater than mean annual growth.

Periodic annual basal area growth, which ranged from 7.3 to 8.0 square feet per acre for the study period, did not differ significantly among treatments (table 2). Mean annual basal area growth ranged from 8.6 to 9.2 square feet per acre. Between 1955 and 1969 periodic annual diameter increment on plots row thinned twice was significantly less than on other plots. Thus, over the 15-year period trees on plots row thinned twice grew from 1.0 to 1.3 inches less than trees on all other plots in the test.

[1] All differences mentioned in the results section are statistically significant at the 0.05 level according to analysis of variance and Duncan's new multiple range test.

Table 2.—*Basal areas and diameters, by thinning treatment*

Stand character and year	Two rows cut	One row cut	Light selection	Moderate selection
Basal area		SQUARE FEET		
1955	150.8	144.7	148.3	139.4
Cut	142.9	158.5	147.3	144.7
1969	118.0	105.4	120.6	105.1
Periodic annual growth	7.3	7.9	8.0	7.4
Diameter		INCHES		
1955	4.7	4.4	4.6	4.4
1969	10.1	10.9	11.0	11.1
Periodic annual growth	.36	.43	.43	.45

Table 1.—*New volume growth by thinning treatment* [1]

Stand character and year	Unit of measure	Two rows cut	One row cut	Light selection	Moderate selection
Volume present					
1955	Cu. ft.	1,694	1,621	1,658	1,553
Cut	Cu. ft.	2,503	2,686	2,639	2,461
1969	Cu. ft.	3,724	3,369	3,852	3,368
Mean annual growth					
1941-1969	Cu. ft.	215	209	224	201
1941-1969	Cords	2.8	2.8	2.9	2.6
Periodic annual growth					
1955-1969	Cu. ft.	302	296	322	285
1955-1969	Cords	4.0	3.9	4.2	3.8
1955-1969	Percent [2]	14.9	16.7	15.5	16.0

[1] Volume inside bark for trees 4 inches d.b.h. and larger.

[2] Based on average of residual volumes after each cut.

At age 29, dominant crop trees averaged 80 feet in height. Average diameter by treatment ranged from 10.2 to 11.3 inches. Two consecutive row thinnings restricted the diameter growth of crop trees. In 15 years they put on 0.6 inch less diameter increment than the crop trees on the two best treatments. Periodic annual cubic growth of crop trees, which ranged by treatment from 110 to 123 cubic feet per acre, did not differ significantly among treatments.

During the first 6 years of the test many very small suppressed trees died on all plots. Since 93 percent of the trees that died during the 15-year study were small, the volume loss was negligible. After the sixth year, mortality averaged about one tree per acre for all treatments. Most of the plots suffered no losses during the last 3 years of the study.

DISCUSSION

None of the growth differences among treatments were large. Cubic growth was excellent on all plots and did not differ significantly among treatments up to age 26. By age 29 periodic annual cubic growth was highest on the lightly thinned selection plots. Removal of a single row in combination with selective thinning yielded the highest annual cubic growth percent during the study period.

Row thinning is very economical because the work can be done rapidly by machine. Daily production is increased, and labor, marking, and administrative costs can be reduced considerably depending on how much of the stand is row thinned. However, unmodified row thinning compels the retention of some undesirable trees which would be removed early in selective thinning. This reduces average tree diameter and lowers stand quality to some extent *(1, 2, 3, 4)*. Furthermore, cutting whole rows removes thrifty trees and denies the forester control of thinning intensity.

Of the four treatments tested, the combination of row and selection thinning applied from the start seems the most practical. In stands where there is no shortage of crop-tree candidates, row thinning places no serious restrictions on crop-tree spacing or their development into large high-quality timber. Where potential crop trees are few and poorly distributed, selective thinning provides greater latitude for favoring the best trees.

LITERATURE CITED

1. Enghardt, H. G.
   1969. Row or selection thinning? Forests and People 19(2): 34-35, 45.

2. Belanger, R. P., and Brender, E. V.
   1968. Influence of site index and thinning on the growth of planted loblolly pine. Ga. Forest Res. Counc. Res. Pap. 57, 7 p.

3. Gilmore, A. R., and Boggess, W. R.
   1969. Growth and yield from row thinnings in a shortleaf pine plantation in southern Illinois. Ill. Agric. Exp. Stn. Forest. Note 126, 3 p.

4. Little, S., Mohr, J. J., and Mook, P. V.
   1968. Ten-year effects from row thinnings in loblolly pine plantations of eastern Maryland. USDA Forest Serv. Res. Note NE-77, 8 p. Northeast. Forest Exp. Stn., Upper Darby, Pa.

SOUTHERN FOREST EXPERIMENT STATION

1971

U.S. FOREST SERVICE RESEARCH NOTE

SO-124

Forest Service, U.S. Dept. of Agriculture

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PROLONGED FLOODING INHIBITS GROWTH OF LOBLOLLY PINE SEEDLINGS

James D. Burton

SOUTHERN FOREST EXPERIMENT STATION

Subsequent growth of potted 2-year-old Pinus taeda *L. seedlings was retarded by flooding to the soil surface for 14 or 21 weeks beginning January 3. After flooding, normal drainage was restored until November 17, when plants were harvested. Flooding for 14 and 21 weeks affected stem height, dry weight of roots and new stem, average needle length, and number of growth flushes. Dry matter in foliage decreased with increasing flooding duration; mineral concentrations did not.*

Some lands formerly considered too wet are now intensively managed for loblolly pine (*Pinus taeda* L.) pulpwood production, and some plantations have had their formerly good natural drainage changed by reservoirs, roads, or other earthworks. Typically, such areas are flooded in late winter, the wet season in the Gulf Coastal Plain. This note describes the effects of winter flooding on loblolly pine seedlings in pots. All factors were held constant except length of flooding and seedling size.

METHODS

Loblolly pine seeds were produced through controlled pollination to insure genetic uniformity. Flowers on a single female parent were fertilized with pollen from a single male parent. Seeds were sown in a nursery, and in December 1965 the 1-0 seedlings were lifted and immediately planted in 13-gallon plastic pots in which they were grown for 1 year before treatments were imposed. Each pot was 20 inches tall and 13 inches in top diameter and had a drain hole at the bottom.

Potting soil was a composite of surface loam (44:47:9 percent sand, silt, and clay) from a forested site in the Quachita River floodplain. Organic matter content, determined by wet-combustion with additional heating (*4*) averaged 3.15 percent; pH of a 1:2 soil: water slurry was 5.5.

Potted plants were arranged in rows in full sunlight; they were spaced 40 inches between pot centers and 5 feet between rows to prevent

mutual shading. Pots were surrounded with sawdust to moderate extremes in soil temperature (fig. 1). Trees were randomly assigned to row and position.

Water was applied to each pot until soil surface was submerged, two or three times weekly until May 1 and daily thereafter. Soil moisture supply may occasionally have been less than transpirational need, but all pots were treated alike.

Stem height was measured in December 1966, and trees were grouped into three size classes. Positions in rows remained unchanged. Trees were randomly assigned flooding treatments within size classes. Seedlings were flooded by plugging the pot drain hole for 0, 7, 14, or 21 weeks, beginning January 3, 1967. Treatment was terminated by removing drain stoppers; watering continued unchanged. The four flooding durations, three size classes, and three complete replications required a total of 36 trees.

Stem height, in cm., was measured from rim of pot to tip of apical bud. Stem diameter, in mm., was measured in an east-west direction with a caliper at the level of the pot rim. Length of one needle in each of three 3-needle fascicles was recorded in mm. On each subsequent growth flush, three fascicles were selected and marked, and needle length was measured. All fascicles selected were among those first formed in each flush, on the south side of the main stem. All these measurements were made at 2-week intervals.

Trees were harvested on November 17, 1967. Soil was washed away, and roots were ovendried and weighed. Needles were removed from each tree, a sample of 100 fascicles from the first flush of 1967 was retained, and all remaining current-year foliage was ovendried and weighed. The 100-fascicle sample was washed in distilled water, ovendried, ground to pass a 20-mesh screen, ashed at 450° C. for 4 hours, and the ash taken up in an extracting solution. Phosphorus

Figure 1. — *The boxed, insulated rows of potted seedlings stood outdoors on a concrete slab.*

content was determined colorimetrically by the vanadomolybdophosphoric yellow method *(3)*; K, Na, and Ca by flame photometry *(3,5)*; and Mg colorimetrically by a thiazole yellow method.

Foliage samples for chemical analysis were taken only from the first current-year flush, because later-flush needles in trees given prolonged flooding were stunted and chlorotic.

RESULTS

Flooding for 21 weeks depressed growth in height, stem diameter, and needle length by 15 to 26 percent and reduced the number of growth flushes. Fourteen-week flooding produced smaller depressions. Elongation of needles in the first flush ceased on July 7 and flushing stopped on August 4 for 2 weeks, during which many of the marked fascicles were broken off by wind. Data on flushing and needle length, therefore, are reported in table 1 for midsummer rather than later. All other data in the table represent conditions at the end of the growing season.

Foliage dry weight declined about 2 grams per tree for each week of flooding. Dry weights of roots and new shoots were influenced to lesser degrees. Foliar nutrient concentrations did not decrease with prolonged (14 to 21 weeks) flooding, but nutrient weights (foliar dry weight x nutrient concentration) did – because foliage dry weight decreased considerably.

Total number of growth flushes did not vary greatly with flooding duration, but second flushes were delayed 10 weeks and third flushes 2 to 4 weeks in trees flooded for 21 weeks. Growth in stem height, stem diameter, and needle length were similarly delayed.

Analysis of variance indicated that significant (0.05 level) differences lay between prolonged (14 to 21 weeks) and brief (0 to 7 weeks) flooding. Results were not significantly influenced by seedling size class or by size-duration interaction. The longer flooding treatments decrease growth, in part because treatment extended into the growing season. Roots of mesophytic plants soon begin to die in soils deprived of oxygen during the growing season.

In this study, stem height, diameter, and weight, total needle length, number of flushes, and root weight were all greatest after 7 weeks of flooding. Brief dormant-season flooding may therefore improve seedling growth. Practically all the soil nitrogen and much of the sulfur and phosphorus are held in organic combinations

Table 1. – *Effect of flooding duration on characteristics of 3-year-old seedlings*

Character and unit of measure	Weeks of flooding			
	0	7	14	21
Stems				
Height growth, mm.	716	738	615	576
Diameter growth, mm.	169	180	159	143
Total flushes in 9 trees, number	23	25	22	18
Dry weight of new stems, g.	53	56	44	46
Needles (current year only)				
Length in first flush, mm.	124	122	117	104
Length in all flushes, mm.	2,350	2,525	2,025	1,750
Dry weight, g.	121	106	97	83
Dry weight of living roots, g.	131	137	122	107
Nutrients in foliage				
Nitrogen, g.	1.34	1.15	1.08	1.07
Phosphorus, g.	.14	.12	.12	.11
Potassium, g.	.54	.45	.39	.40
Calcium, g.	.28	.25	.24	.19
Magnesium, g.	.12	.12	.10	.08
Sodium, g.	.028	.024	.024	.019

(2). If soils contain ample organic matter and remain unfrozen, as these did, organic matter may be attacked during flooding by anaerobic microorganisms *(1)*, releasing nutrients which become more readily available to plants after aeration is restored.

Results of this study indicate that, whereas brief dormant-season saturation of the soil may cause no loss of growth in seedling stands, prolonged continuous flooding does.

LITERATURE CITED

1. Bonner, F. T., and Ralston, C. W.
   1968. Oxidation-reduction potential of saturated forest soils. Soil Sci. Soc. Am. Proc. 32: 111-112.
2. Buckman, H. O., and Brady, N. C.
   1960. The nature and properties of soils. Ed. 6, 567 p. N. Y.: The Macmillan Co.
3. Jackson, M. L.
   1958. Soil chemical analysis. 498 p. Englewood Cliffs, N. J.: Prentice-Hall.
4. Richards, L. A. (Ed.)
   1954. Diagnosis and improvement of saline and alkali soils. USDA Agr. Handbook 60, 160 p.
5. Wells, C. G., and Corey, R. B.
   1960. Elimination of interference by phosphorus and other elements in the flame photometric determination of calcium and magnesium in plant tissue. Soil Sci. Soc. Am. Proc. 24: 189-191.

SOUTHERN FOREST EXPERIMENT STATION

1971

U.S. FOREST SERVICE RESEARCH NOTE

SO-125

Forest Service, U.S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

JAN 5 1972

RELEASING SHORTLEAF PINES INCREASES CONE AND SEED PRODUCTION

Herbert A. Yocom

SOUTHERN FOREST EXPERIMENT STATION

Removal of all trees within 30 feet of shortleaf pine seed trees increased cone production and the percentage of sound seeds per cone over that of paired, unreleased trees.

This note describes the effects of release on cone and sound seed production of dominant shortleaf pine (*Pinus echinata* Mill.) trees in the Ouachita Mountains of Arkansas. In a previous study in Missouri, seed production of shortleaf pine varied with thinning intensity in the overstory and with removal of understory hardwoods *(4)*. Other studies have shown that thinning increases cone production of loblolly (*Pinus taeda* L.) and longleaf (*P. palustris* Mill.) pines *(1, 2, 3, 5)*, and that production is related to diameter, crown size, and past cone bearing *(5)*.

METHODS

Study trees of varying diameters were located on a range of sites. The sites selected had average site indexes of 45, 55, and 65 feet at age 50 years. On each site pairs of trees were selected that had diameters at breast height falling in nominal 2-inch classes of 8, 12, and 16 inches. The members of the pairs were located near each other, were about the same age, had similar sized crowns, had about equal levels of past cone production as judged by the number of old cones still on the trees, and had similar amounts of competition. Three pairs (replications) were selected in each of the nine site-diameter classes. One randomly selected tree of each pair was not released. The other was released by cutting all pines and cutting or frilling all hardwoods within a 30-foot radius. The hardwood frills and stumps were sprayed with 2,4,5-T to minimize sprouting.

Release was completed in June 1963, and the maturing cones on each tree were counted annually in August or September of 1963 through 1967. Counts were made by climbing into the tree crowns and carefully observing all visible cones, branch by branch, from the most

advantageous position within the crown, changing positions as necessary.

Since the 1963 cones were well on their way to maturity and the conelets for the 1964 crop were already established when the trees were released, it was assumed that the crops in these 2 years would not be affected by treatment. Accordingly, production of treated and untreated trees in these 2 years was considered an indicator of the similarity of the paired trees before treatment. Cone production figures for these years taken singly and together did not differ significantly by treatment at the 0.05 level. Average number of cones per tree was 94 in 1963 and 74 in 1964.

Production figures for the years 1965 through 1967 were totalled for each tree, and differences were tested for statistical significance by analysis of variance. The 0.01 level was applied to measure effects of release, and the 0.05 level to discover whether the response to release varied by site or diameter class. The average number of sound seeds per cone was computed for each tree, and these averages were similarly analyzed. Diameter and height of study trees were measured before treatment and at the end of the study, and growth was computed and analyzed. Only statistically significant differences are mentioned in the description of results.

RESULTS

Release approximately doubled the average cone production per tree. Between 1965 and 1967, untreated trees produced an average of 498 cones, while released trees produced 1,069. This response to treatment did not differ significantly by site or diameter class.

Release also increased the average number of sound seeds per cone significantly. In 1966 and 1967 cones from unreleased trees contained an average of 35 sound seeds, while those from released trees contained 38. The percentages of sound seed were 81 for unreleased and 85 for released trees.

No consistent relationship was observed between the proportion of sound seeds and the number of cones on individual trees.

Treatment increased both diameter and height growth. Between 1963 and 1967 unreleased trees grew an average of 0.40 inch in d.b.h. and 2.2 feet in height. Averages for released trees were 1.04 inches and 4.1 feet.

LITERATURE CITED

1. Allen, R. M.
   1953. Release and fertilization stimulate longleaf pine cone corp. J. Forest. 51: 827.
2. Croker, T. C.
   1952. Early release stimulates cone production. USDA Forest Serv. South. Forest Exp. Stn., South. Forest. Notes 79.
3. Easley, L. T.
   1954. Loblolly pine seed production areas. J. Forest. 52: 672-673.
4. Phares, R. E., and Rogers, N. F.
   1962. Improving shortleaf pine seed production in Missouri. J. Forest. 60: 322-324.
5. Wenger, K. F.
   1954. The stimulation of loblolly pine seed trees by preharvest release. J. Forest. 52: 115-118.

SOUTHERN FOREST EXPERIMENT STATION

1971

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SITE INDEX CURVES FOR LOBLOLLY AND SHORTLEAF PINE PLANTATIONS ON ABANDONED FIELDS IN TENNESSEE, ALABAMA, AND GEORGIA HIGHLANDS

Glendon W. Smalley[1] and David R. Bower[2]

SOUTHERN FOREST EXPERIMENT STATION

Equations relating tree height to age were prepared from data gathered in 270 loblolly and 104 shortleaf pine plantations:

Log loblolly height $= 2.233683 - 2.450976\ Age^{-1/2}$

Log shortleaf height $= 2.248642 - 2.896448\ Age^{-1/2}$

Curves for both species are for ages from 10 to 40 years.

Loblolly (*Pinus taeda* L.) and shortleaf (*P. echinata* Mill.) pines have been planted on many abandoned fields in the Ridge and Valley, Cumberland Plateau, Eastern Highland Rim, and Western Highland Rim regions of Tennessee, Alabama, and Georgia (fig. 1). This note provides equations and curves for estimating future heights of pines planted in the southern highlands when present height and age are known.

Since almost all pine plantations in the regions were established after 1930, site index age was set at 25 rather than the more standard 50 years. Index age refers here to the total age of the trees from seed.

STUDY METHODS

Data were collected during a comprehensive study of plantation volumes and yields. Average heights and ages were recorded in 302 loblolly and 116 shortleaf pine plantations. To be sampled, plantations had to meet certain specifications:

1. be at least 10 years old from seed,
2. be unthinned,
3. be unpruned,
4. be unburned,
5. be void of reinforcement planting,
6. have reasonably good survival and tree distribution,
7. show no evidence of severe insect or disease attack, and
8. in loblolly stands have ice or snow damage on no more than 25 percent of the trees.

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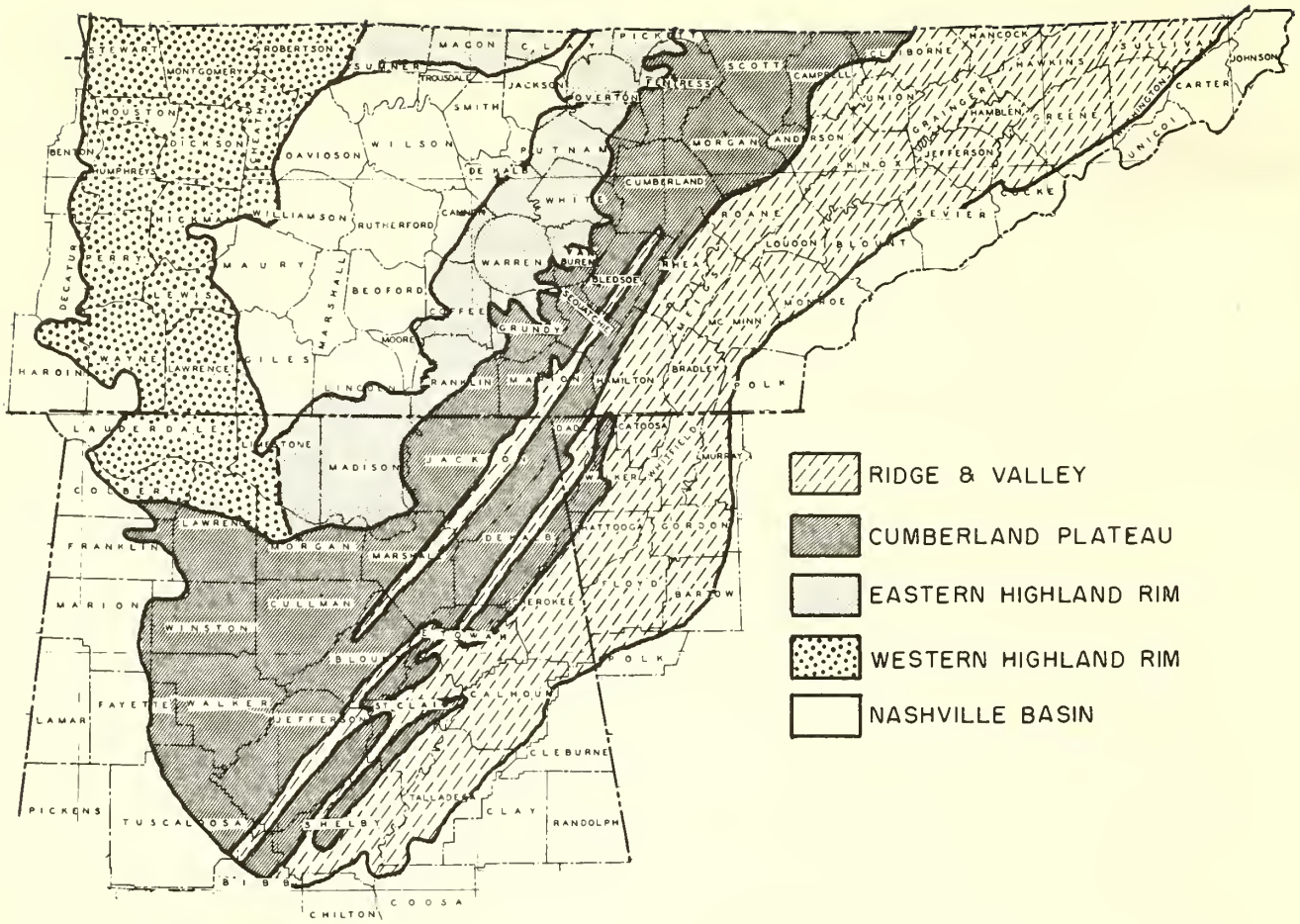

Figure 1. — *Physiographic regions of central Tennessee, northern Alabama, and northwestern Georgia.*

Most pine plantations in the area contain some competing vegetation. Quantity of competition was not a criterion except as it influenced pine survival and distribution.

Heights and ages from 270 loblolly and 104 shortleaf plantations were used to develop a mathematical model relating height to age. Thirty-two loblolly observations and 12 shortleaf were withheld to test the goodness of fit of the models that were developed. Withheld observations were randomly selected at a rate of about 10 percent per physiographic province.

For each species, average total height was calculated from measurements of sample trees on 0.05-acre plots. Every fourth tree in each 1-inch d.b.h. class was measured with a Haga altimeter to the nearest foot. Age from seed was determined by counting annual rings at ground level on a felled tree.

Loblolly ages ranged from 10 to 31 years, average heights of dominant and codominant trees from 22 to 72 feet, and site indexes from 31 to 89 (table 1). Shortleaf ages ranged from 11 to 35 years, average heights from 21 to 66 feet, and site indexes from 26 to 58 feet (table 2). Age did not appear to be correlated with site index in either case.

RESULTS

Height on age relations were best expressed by

$$\text{Log } H = b_0 + b_1 A^{-1/2} \qquad \text{EQ. I}$$

where Log = logarithm to the base 10.
H = total tree height in feet
A = age from seed in years
b_0, b_1 = regression coefficients

Within species, separate regressions were determined for each physiographic region and for all regions. The combined regressions for each species were accepted after covariance analyses showed no significant differences (0.01 level)

Table 1. — *Distribution of loblolly plantations by age, site index, and physiographic province*

(A)

Physiographic province	Site Index													Total
	30	35	40	45	50	55	60	65	70	75	80	85	90	
RV	1		2	2	16	17	17	12	3					70
CP		1	2	4	16	25	10	7	3	1			1	70
EHR			1	4	10	29	15	8	3					70
WHR				6	16	22	13	2	1					60
Total	1	1	5	16	58	93	55	29	10	1			1	270

(B)

Physiographic province	Age					Total
	10-14	15-19	20-24	25-29	30-34	
RV	21	17	17	15		70
CP	48	11	2	6	3	70
EHR	35	19	8	7	1	70
WHR	17	15	10	15	3	60
Total	121	62	37	43	7	270

(C)

Age	Site Index													Total
	30	35	40	45	50	55	60	65	70	75	80	85	90	
10-14			1	4	8	20	43	25	15	3	1		1	121
15-19				1	6	14	18	12	7	4				62
20-24	1				2	11	11	9	2	1				37
25-29						13	20	6	4					43
30-34							1	3	1	2				7
Total	1	1	5	16	58	93	55	29	10	1			1	270

Table 2. — *Distribution of shortleaf plantations by age, site index, and physiographic province*

(A)

Physiographic province	Site Index								Total
	25	30	35	40	45	50	55	60	
RV	1	1	1	7	16	18	11	1	56
CP				1	10	3	2		16
EHR			1	2	6	8	3		20
WHR				7	1	3		1	12
Total	1	1	2	17	33	32	16	2	104

(B)

Physiographic province	Age						Total
	10-14	15-19	20-24	25-29	30-34	35-39	
RV	1	5	7	36	5	2	56
CP	11	1			4		16
EHR	9	2	6	3			20
WHR		2	1	7	1	1	12
Total	21	10	14	46	10	3	104

(C)

Age	Site Index								Total
	25	30	35	40	45	50	55	60	
10-14				2	8	7	4		21
15-19				4	3	2	1		10
20-24	1		1	1	4	6	1		14
25-29		1	1	8	13	14	8	1	46
30-34					5	2	2	1	10
35-39				2		1			3
Total	1	1	2	17	33	32	16	2	104

between physiographic regions in either slopes or intercepts.

The guide curve equation for loblolly pine was EQ. II

$$\text{Log } H = 2.233683 - 2.450976A^{-1/2}$$

Mean log H = 1.612667

Root mean square residual = 0.05533

$r^2 = 0.9988$

For 19 of the 32 withheld plots, the predicted height fell in the same 5-foot class as the actual height (table 3). In three plots the predicted value fell in the class immediately above that containing the true value, whereas in nine plots it fell in the class immediately below. In only one plot did the predicted value lie as much as two classes removed from the actual height. Sixty-nine percent of the estimates were within ±10%, and 94% were within ±15% of the observed heights. The average algebraic percent error was −0.90, which corresponds to a height difference of slightly less than 0.4 foot for the tree of mean height.

Table 3. — *Frequency distribution of differences between predicted and observed tree heights*

Difference (feet)	Plots
	Number
LOBLOLLY	
+ 7.6 to + 12.5	1
+ 2.6 to + 7.5	3
+ 2.5 to − 2.5	19
−2.6 to − 7.5	9
Total	32
SHORTLEAF	
+ 12.6 to + 17.5	1
+ 7.6 to + 12.5	0
+ 2.6 to + 7.5	2
+ 2.5 to − 2.5	5
− 2.6 to − 7.5	3
− 7.6 to −12.5	1
Total	12

The guide curve was rearranged to estimate total tree height as a function of site index and age. EQ. III

$$\text{Log } H = \log SI + 2.460976(25^{-1/2} - A^{-1/2})$$

This equation was solved for selected combinations of site index and age and standard site index curves were prepared (fig. 2). The curves have been extended to age 40 years by assuming that the present height on age relationship will not change.

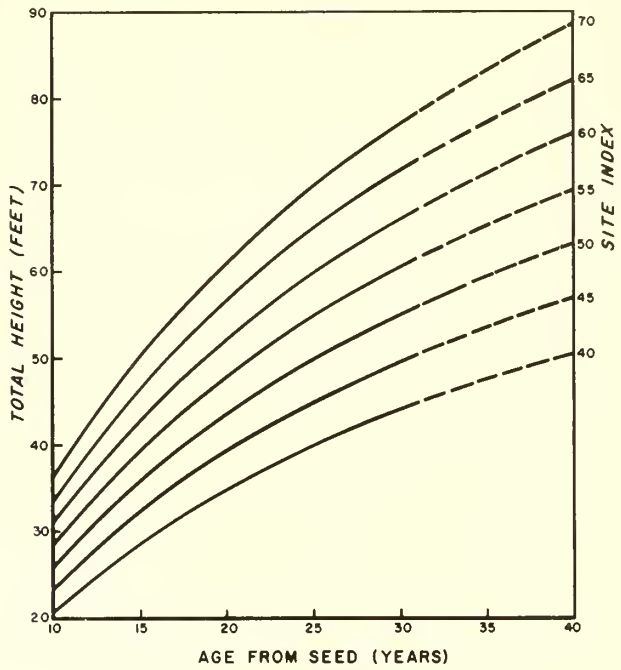

Figure 2. — *Site index curves at age 25 years from seed for loblolly pine plantations on abandoned fields in Tennessee, Alabama, and Georgia Highlands. Dashed lines indicate extrapolation.*

The guide curve equation for shortleaf pine was

EQ. IV

$$\text{Log } H = 2.248642 - 2.896448A^{-1/2}$$

Mean log H = 1.614794

Root mean square residual = 0.05651

$r^2 = 0.9988$

On five of 12 withheld plots, the predicted height fell in the same 5-foot height class as the actual height (table 3). In two plots the predicted value fell in the class immediately above that containing the true value, whereas in three plots it fell in the class immediately below. For two plots the predicted value was as much as two classes removed from the actual height. Seventy-five percent of the estimates were within ±10% of the observed heights. The average algebraic percent error was +0.79, which corresponds to a height difference of slightly more than 0.3 foot for the tree of mean height.

The guide curve was rearranged to estimate total tree height as a function of site index and age. EQ. V

$$\text{Log } H = \log SI + 2.896448(25^{-1/2} - A^{-1/2})$$

This equation was solved for selected combinations of site index and age and site index curves were drawn (fig. 3). These curves also were extended to age 40 years.

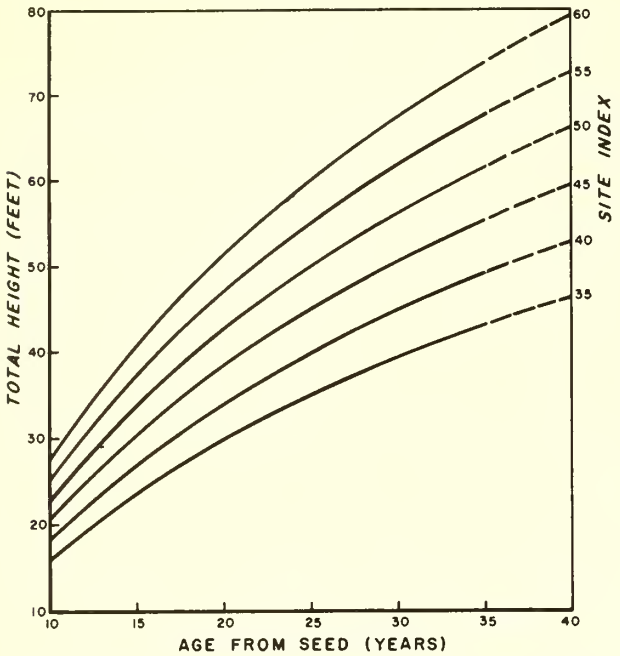

Figure 3. — *Site index curves at age 25 years from seed for shortleaf pine plantations on abandoned fields in Tennessee, Alabama, and Georgia Highlands. Dashed lines indicate extrapolation.*

USING THE EQUATIONS AND CURVES

To estimate site index for a particular plantation, determine total age and average height of dominant and codominant trees. For example, suppose a loblolly plantation was planted 19 years ago with 1-year-old seedlings. The age from seed is now 20 years. Suppose, also, that seven of the tallest trees in the plantation have heights of 50, 55, 53, 52, 49, 55, and 54 feet for an average height of 52.6 feet. Referring to figure 2 we find that this plantation has a site index of 60, i.e., these trees should average 60 feet tall in 5 more years.

For maximum accuracy, tree height to the nearest foot and age to the exact year should be entered in Equation III or V (rearranged to predict log SI) rather than interpolated from the site index curves. Rearranged, Equations III and V can also be inserted into computer programs to determine site index for growth and yield studies, forest inventories, and management plans in which total heights and ages are available.

Prediction of heights beyond the range of the data should be undertaken with caution. Extrapolation is reasonable only if the curves or equations are used to determine relative indices of site productivity.

ACKNOWLEDGEMENTS

For the basic data in this note the Southern Forest Experiment Station is indebted to the 171 private landowners and 25 industries, agencies, and other organizations that made their plantations available for study.

The authors thank Kenneth Pierce, Southern Forest Experiment Station, and John C. Allen, Tennessee Valley Authority, for help in gathering data.

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BINOCULAR COUNTS OF LONGLEAF PINE STROBILI

Thomas C. Croker, Jr.[1]

SOUTHERN FOREST EXPERIMENT STATION

In south Alabama binocular counts of longleaf pine flowers and conelets made during a spring "naked season" accounted for about 60 percent of the total on the trees. Counts were considerably less complete if made before flowers had fully formed or after needle growth had begun. Independent observations by two men were not significantly different.

Advance estimates of seed crops are essential to southern pine silviculture, and numerous methods have been developed for making them. One approach is to count all flowers and conelets visible from the ground with binoculars, and then multiply by a factor that adjusts for strobili not seen. Studies have shown that the procedure is accurate in slash, shortleaf, and loblolly pine *(2, 3, 4, 5, 6)*. This note presents results for longleaf pine.

PROCEDURE

Fifty longleaf pine (*Pinus palustris* Mill.) seed trees were selected on the Escambia Experimental Forest in southern Alabama, and two observers counted flowers and conelets on them once in April and once in May of 1968. The counts were repeated, with the same observers but on 50 similar trees, in April, May, and June of 1969. The observers had hand-held 7 x 50 binoculars and stood with the sun at their backs, about two stem lengths away from individual trees. They counted all flowers and conelets that could be seen without moving. They routinely began in the lower left extremity of the crown, worked toward the stem and back to the edge until the tip was reached, and then went down the other half of the crown. Immediately after the last count of each year, all trees were felled and the actual number of strobili on each was determined.

In longleaf pine, 18 to 19 months typically elapse between flower appearance and seed

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ripening. In spring, therefore, trees contain both new flowers and conelets from the previous year *(1)*. The flowers appear before growth of new needles begins and are highly visible for 2 weeks or so. Conelets also are readily seen, and thus counts made at this time yield data for predicting seed crops both in the coming fall and in the following year. Since the "naked period" varies with latitude and local weather, an effort was made to define it in terms of heat sums—that is, by summing the daily maximum degrees exceeding 50°F. beginning January 1 and ending the day of the binocular counts.

RESULTS

The counts in April confirmed that observers working before the naked season will overlook numerous flowers and conelets (fig. 1). The percentage of strobili detected in these early counts ranged from 21 to 34. During the naked period, by contrast, about 60 percent of all strobili were seen. By then, flowers were fully developed and late conelets had changed color and begun to enlarge.

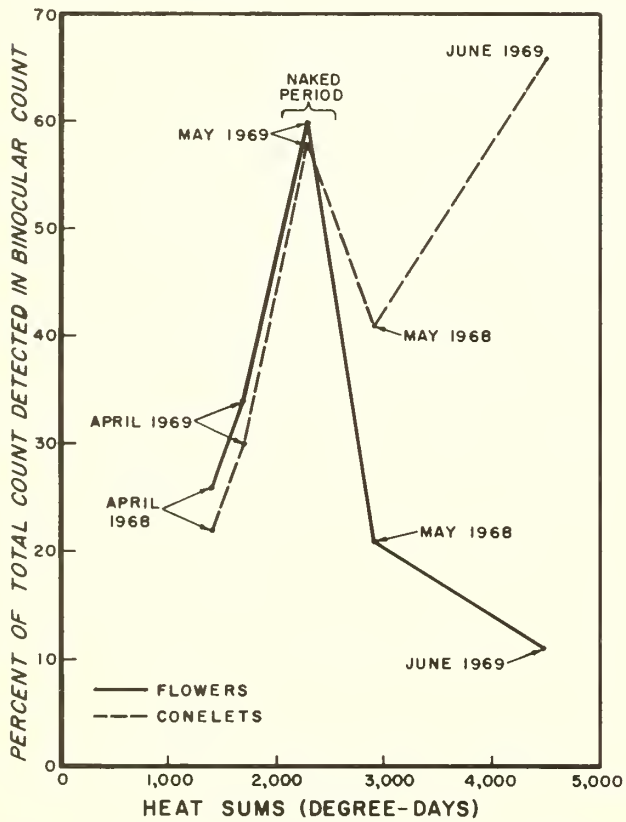

Figure 1. — *Proportion of flowers and conelets detected in binocular counts, in relation to "naked period" and heat sums.*

After the naked period, counts declined sharply as flowers advanced into the early conelet stage and became hidden by new needles. Counts of late conelets declined also, but by June the conelets had developed into the green cone stage and had reached sizes at which they could be readily seen among the needles.

Statistical analysis was limited to the count of May 1969, the only one made during the naked period. A test revealed no significant difference between observers, and the two sets of 50 observations were therefore combined. Regressions computed from the pooled data indicated that a conservative estimate of either flowers or conelets could be had simply by multiplying binocular counts by a factor of 1.5.

Heat sums totaled about 2,000 degree-days when the naked period began and about 2,500 when it ended. These values must be regarded as tentative, as they represent 1 year's observations in one location.

APPLICATION

The factor of 1.5 probably is applicable to other longleaf stands, provided that the observers work during the naked season and follow approximately the procedures described for this study. A reliable mean estimate for a regeneration or cone-collection area will usually require counts on at least 50 trees. If greater precision is desired, local regressions should be derived by comparing binocular observations with counts on felled trees.

LITERATURE CITED

1. Croker, T. C., Jr.
1971. Female strobilus stages of longleaf pine. J. Forest. 69: 98-99.
2. Hoekstra, P. E.
1960. Counting cones on standing slash pine. USDA Forest Serv. Southeast. Forest Exp. Stn. Res. Note 151, 2 p.
3. Seidel, K. W.
1970. Estimating cone yield of shortleaf pine. USDA Forest Serv. Tree Planters' Notes 21(3): 10-11.

4. Vanhaverbeke, D. F., and Barber, J. C.
1964. Seed crop estimation in a loblolly pine seed production area. Ga. Forest Res. Counc. Res. Pap. 21, 5 p.
5. Webb, C. D., and Hunt, D. L.
1965. Seed crop estimation in a slash pine seed production area. Ga. Forest Res. Counc. Res. Pap. 28, 5 p.
6. Wenger, K. F.
1953. How to estimate the number of cones in standing loblolly pine trees. USDA Forest Serv. Southeast. Forest Exp. Stn. Res. Note 44, 2 p.

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SLASH PINES RESPOND EQUALLY TO NITROGEN APPLICATIONS IN FALL AND SPRING

W. H. McKee, Jr., and R. A. Sommers[1]

SOUTHERN FOREST EXPERIMENT STATION

Three-year-old slash pine seedlings growing in pots responded equally to fall and spring applications of nitrogen in terms of height growth, total weight, and nitrogen recovery. Total uptake of nitrogen during the growing season after application increased with amount applied. Utilization of nitrogen was not associated with carbohydrate levels in roots.

Response of herbaceous plants to nitrogen fertilization varies with season of application in a way that is related to the quantity of food reserves in the roots *(4)*. The study described here was done to determine if slash pines (*Pinus elliottii* Engelm.) respond similarly, and if carbohydrate levels of roots are drastically reduced immediately after the fertilizer is applied. Nitrogen was applied in fall and spring at the beginning and the end of a single dormant season. Trends in root reserves of shortleaf pine (*Pinus echinata* Mill.) *(2)* as well as northern conifers *(6)* suggested that carbohydrate levels might differ markedly in fall and spring.

METHODS

Study trees were selected from a 2-year-old plantation on a Beauregard silt loam that had never been cultivated. Grade 2 seedlings *(11)* had been hand-planted and were 30 to 45 cm. tall in July 1967 when they were potted. Seedlings were lifted with a ball of soil approximately 20 cm. in diameter and planted in 25-cm. plastic pots. The opening around the root balls was filled with pulverized soil from the surrounding area. Air pockets were eliminated by thoroughly soaking the soil with water and allowing it to settle.

Seedlings were assigned to each of six treatments consisting of all combinations of two seasons of application, fall and spring, and three levels of nitrogen, none, 150 pounds, and 300 pounds of nitrogen per acre. Nitrogen was

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applied at 0, 2.55, and 5.10 g. of ammonium nitrate per pot. The fall application coincided with setting of winter buds (October 23, 1967) and the spring application with resumption of spring growth (April 5, 1968).

Three grams of triple superphosphate (equivalent to 220 pounds of phosphorus per acre) were applied to each pot to insure an optimum response to N.

Pots were placed on a plastic sheet in a bed of wood chips to insulate the soil from rapid temperature changes.

Carbohydrate content of roots was measured when fertilizers were applied, 7 and 14 days after each application, and at the end of the study in mid-September 1968. Seedling heights were measured at the beginning and the end of the study. Ovendry (70° C.) weights of needles, stems, and roots were also obtained at the end of the test, and nitrogen contents of the three plant parts were determined.

Because each measurement required that a plant be sacrificed, treatment plots contained different numbers of pots. Five pots were required for each plot fertilized in fall and four for each fertilized in the spring. Treatments were replicated five times with trees blocked on the basis of initial height. Differences among means were tested for statistical significance at the 0.05 level of probability.

For the carbohydrate determination, root segments 3 to 5 mm. in diameter were freeze-dried and ground to pass a 40-mesh screen. Ethanol-soluble sugars were extracted by boiling in 80 percent ethanol for 30 minutes. Total carbohydrates were extracted by boiling in 0.2 N H_2SO_4 for 1 hour as outlined by Smith et al. *(9)*. Reducing power of the extracts was determined by the method of Somogyi *(10)* with glucose as a standard. Results are expressed as percent carbohydrate on a dry-weight basis. The total carbohydrate extraction approximated the ethanol-soluble sugars plus starch.

Nitrogen content of ovendried plant material was determined by the Kjeldahl method *(1)*.

RESULTS

Nitrogen applied in both seasons increased height growth, dry weight, and total nitrogen content of the seedlings (table 1). Season of application had no effect on height growth, weight, or nitrogen content of seedlings. After adjustment by covariance to account for differences in initial height, each additional application of 150 pounds of nitrogen was shown to have increased height by 3 to 4 cm. Trees that received 300 pounds of nitrogen were significantly taller than the checks, but those receiving 150 pounds did not differ significantly in height from the checks or those given the higher nitrogen level.

Table 1. — *Effect of nitrogen treatments on height growth, dry weight, and total nitrogen content of 3-year-old slash pine at end of study*

Nitrogen applied (lbs. per acre)	Adjusted final height	Dry weight	Total nitrogen content
	Centimeters	*— Grams —*	
0	68.2 b[1]	[2]106.6	[2]0.50
150	72.7 ab	143.8	.71
300	76.0 a	176.9	.95

[1] Values in column followed by the same letter do not differ significantly at the 0.05 level.

[2] Dry weight and total nitrogen content showed a significant linear response to nitrogen levels by polynomial partitioning.

Dry weight of seedlings increased linearly with level of nitrogen. Each addition of 150 pounds of nitrogen increased dry weight about 35 grams.

Total nitrogen content of seedlings ranged from 0.50 to 0.95 grams per plant and also increased linearly with amount of nitrogen applied. In evaluating fertilizer response, it is desirable to know what proportion of the applied nutrients were assimilated by the plant. If plant nitrogen in excess of that found in the control can be taken as uptake of fertilizer, 0.21 and 0.45 grams were recovered from the 150- and 300-pound treatments in which 0.85 and 1.70 grams of N were applied, respectively. Apparently, about 25 percent of the applied N was assimilated by the plant. This level of fertilizer recovery is low compared with the 50 to 80 percent reported for herbaceous plants *(8)*.

Nitrogen had only a slight effect on carbohydrate levels in roots 1 and 2 weeks after fertilization (table 2). The approximately 2-per-

Table 2. – *Effect of nitrogen, season of application, and date after application of N on total carbohydrate levels in roots of slash pine seedlings*

Season and days after application	Pounds per acre			Average all plots
	0	150	300	
	— — — *Percent of dry weight* — — —			
Fall				
[1]0	18.8	16.3	16.8	17.3 c [2]
7	21.8	19.5	18.4	19.9 b
14	22.3	18.7	20.1	20.4 b
Spring				
0	21.3	22.0	25.2	22.8 a
7	24.4	21.4	20.5	22.1 a
14	22.5	20.7	22.7	22.0 a
Average	21.8 A [2]	20.1 B	20.4 AB	---------

[1] Day "0" represents date nitrogen applied. Day 7 and 14 represent 7 and 14 days later, respectively.

[2] Averages followed by the same letter do not differ significantly at the 0.05 level.

centage-point change in total carbohydrate content attributed to 150 pounds of nitrogen amounted to only a 10 percent change in the total carbohydrate content of the roots. Total carbohydrates did not change after fertilization in the spring but increased with time after fertilization in the fall. This change in total carbohydrate content represented about 15 percent of the carbohydrate fraction. The ethanol carbohydrate fraction did not change in the 2 weeks after application of fertilizer.

Ethanol-soluble sugars in roots increased slightly between the time fertilizer was applied in November and the following summer (table 3). The increase amounted to about 1.5 percent of plant weight or about 20 percent of the carbohydrate fraction.

Total contents of carbohydrates as percentages of dry weight were highest in the spring, 21.8 percent, and lowest in September, 14.2 percent. Significant differences were found between spring, fall, and late-summer levels of this fraction. Application of nitrogen did not influence the seasonal change in total carbohydrate content.

Table 3. – *Ethanol-soluble and total carbohydrates in roots after fall application of nitrogen*

Carbohydrate fraction and nitrogen treatment (lbs. per acre)	Date sampled		
	Oct. 23 [1]	April 5	Sept. 18
	— — — *Percent of dry weight* — — —		
Ethanol soluble [2]			
0	7.9	7.4	6.4
150	7.7	9.1	8.3
300	7.1	7.6	7.6
Average	7.6	8.0	7.4
Total			
0	18.8 A [3,4]	22.1 A	12.7 B
150	16.3 B	20.2 B	13.5 B
300	16.8 B	23.2 A	16.5 A
Average	17.3 b [3]	21.8 a	14.2 c

[1] Nitrogen applied on October 23, at time of sampling.

[2] N level did not significantly affect content of ethanol-soluble sugars.

[3] Values followed by the same letter do not differ significantly at the 0.05 level.

[4] Significant differences found on Oct. 23 are not responses to nitrogen since plants did not have time to respond to treatments.

DISCUSSION

As in a previous study *(3)*, nitrogen fertilization stimulated height growth and dry weight of slash pine. Spring and fall applications of nitrogen were equally effective on the potted seedlings of the present study. This result agrees with reports for pines in general except for adverse effects observed for late-summer to mid-autumn fertilization *(5)*. Apple trees growing at a high level of vigor are also reported to show no preference for season of nitrogen application *(7)*. The proportion of applied nitrogen recovered by the trees was disappointingly low—about 25 percent.

Seasonal changes in carbohydrate levels in roots were similar to those reported for shortleaf pine *(2)*. Nitrogen treatments did not drastically alter the carbohydrate levels after either the spring or fall application possibly because nitrogen recovery was poor.

The results indicate that from the standpoint of nitrogen recovery and root carbohydrates one season is probably about as good as another for nitrogen application. In the field, competing vegetation, leaching losses, and volatilization should be considered in choosing a time for applying nitrogen. Season of application may require further study under conditions of improved nitrogen recovery by slash pine.

LITERATURE CITED

1. Association of Official Agricultural Chemists.
   1955. Official methods of analysis. Ed. 8, 1008 p., Washington, D.C.
2. Hepting, G. H.
   1945. Reserve food storage in shortleaf pine in relation to little-leaf disease. Phytopathology 35: 106-119.
3. Jackson, L. W. R., and Cloud, M. C.
   1958. Nitrogen fertilizer increases growth of stem of slash, longleaf pine. Nav. Stores Rev. 68(9): 4-5.
4. Jones, D. I. H., Griffith, G. A. P., and Walters, R. J. K.
   1961. The effect of nitrogen fertilizer on the water-soluble carbohydrate content of perennial ryegrass and cocksfoot. J. Br. Grassl. Soc. 16: 272-275.
5. Kawana, A.
   1966. Method of forest fertilization. I. Potash Rev. 22/18, 5 p.
6. Kruegar, K. W., and Trappe, J. M.
   1967. Food reserves and seasonal growth of Douglas-fir seedlings. Forest Sci. 13: 192-202.
7. Magness, J. R., Batjer, L. P., and Regeimbal, L. O.
   1948. Apple-tree response to nitrogen applied at different seasons. J. Agric. Res. 76: 1-25.
8. Russell, E. W.
   1961. Soil conditions and plant growth. Ed. 9, 688 p. N.Y.: John Wiley and Sons.
9. Smith, D., Paulsen, G. M., and Raguse, C. A.
   1964. Extraction of total available carbohydrates from grass and legume tissue. Plant Physiol. 39: 960-962.
10. Somogyi, M.
    1952. Notes on sugar determination. J. Biol. Chem. 194: 19-24.
11. Wakeley, P. C.
    1954. Planting the southern pines. USDA Agric. Monogr. 18, 233 p.

SOUTHERN FOREST EXPERIMENT STATION

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UPGRADING YELLOW-POPLAR SEEDS

F. T. Bonner[1] and G. L. Switzer[2]

SOUTHERN FOREST EXPERIMENT STATION

Yellow-poplar seed lots can be upgraded considerably by dewinging in a debearder and then cleaning and separating the seeds into four specific-gravity fractions with a fractionating aspirator or a gravity separator. By this process, lots with an original soundness of 6 to 10 percent were upgraded to between 60 and 65 percent full seeds.

Nurserymen have long been plagued by the very low percentage of full seeds in yellow-poplar (*Liriodendron tulipifera* L.) lots. The common results have been expensive handling and stratification procedures, and little or no control over seedling density or distribution in the seedbeds. The inability to obtain uniform lots of high viability, except by X-ray sorting, has also inhibited research with yellow-poplar seeds. This article describes a processing method that has proved highly successful both in small trials and in a larger pilot-scale operation. The method involves removal and separation of the carpel wing and partitioning of the remaining seeds into different weight fractions to isolate the full seeds.

PROCEDURE FOR SMALL LOTS

The seeds' carpel wings were removed in a small debearder designed for seeds of forage grasses or small grains. A rotary horizontal beater inside a steel drum forces the seeds to rub against projecting arms and each other.[3]

The drum of the debearder was filled with intact seeds to about half its capacity, and the discharge gate was blocked for 2 or 3 minutes to insure adequate reduction or removal of the carpels. When visual checks showed that the

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[3]Harmond, J. E., Brandenburg, N. R., and Klein, L. M. *Mechanical seed cleaning and handling.* USDA Agr. Handb. 354, p. 56. 1968.

carpel wings were gone, the discharge gate was partially opened. To maintain a steady flow rate and uniform abrasion, carpels were continually hand-fed into the drum, keeping it about half full. The amount of time necessary for effective dewinging varied by seed lot. Drier carpels were dewinged sooner than moist ones.

The seeds were spearated from the carpel-wing debris with a laboratory model of a fractionating aspirator. The dewinged and cleaned seeds were then rerun through the aspirator and separated into four density fractions. Airflow was adjusted to place the lot's approximate percentage of full seeds, as shown by a prior cutting test, in the heaviest fraction.

The process yielded clean and smooth seeds with flow characteristics entirely different from those of seeds with intact carpels (fig. 1). Processed seeds should flow easily in any cleaning, processing, or planting machinery.

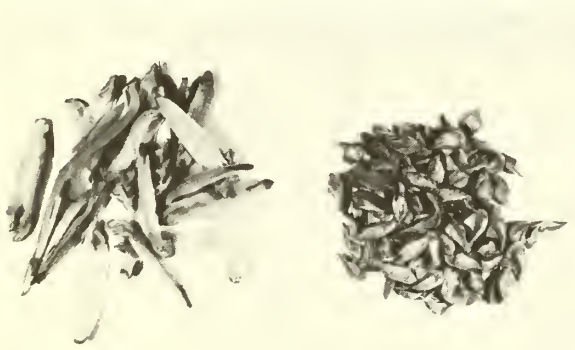

Figure 1. — *Seeds with intact carpels (left), and dewinged and smoothed seeds after processing (right).*

EXPERIMENTAL RESULTS

Two small lots were upgraded by the procedure described:

Lot A—Seeds from a single tree in Warren County, Miss.; cutting tests showed 9 percent full.

Lot B—Seeds from a single tree in Oktibbeha County, Miss.; cutting tests showed 35 percent full.

"Cones" were picked from tree tops in logged areas, air-dried, and broken apart by hand.

Cutting tests after processing showed that the heaviest fractions were 60 and 79 percent full as compared to original lot values of 9 and 35 percent for lots A and B, respectively (table 1).

Table 1. — *Fullness and germinative capacity of two small seed lots*

Aspirator fractions	Proportion of filled seeds	Germinative capacity	
		Total-seed basis	Full-seed basis
	Percent		
Lot A			
1 (heaviest)	60	54	84
2	12	16	100
3	2	4	100
4 (lightest)	2	1	100
Lot B			
1 (heaviest)	79	73	90
2	13	23	100
3	2	2	100
4 (lightest)	1	1	100

As expected, the proportion of full seeds was much lower in the lighter fractions.

Reductions of weight and volume from the original lot were outstanding. Trash and dust removal after dewinging eliminated about one-third of the entire original weight and volume for each lot. Discarding the two lightest fractions (3 and 4) would eliminate an additional 15 percent of the volume in Lot B and about 35 percent in Lot A. Thus, with these lots one-half to two-thirds of the material normally handled could be discarded.

Samples from each fraction were imbibed at room temperature for 48 hours, then stratified in plastic bags at 37° F. for 60 days. Germination was tested on moist Kimpak under an alternating daily regime of 8 hours light at 86° F., and 16 hours dark at 68°. Positive geotropic response of the emerging radicle was the criterion of germination. The test period was 30 days. Germinative capacity values (total seed basis) agreed very well with the cutting tests, with the single exception of fraction 2 in Lot B (table 1). High germinative capacities calculated on full-seed bases show that processing did not harm the seeds.

The number of good seeds in each fraction can be estimated from seed weights (table 2). In Lot B, fraction 1 contained 67 percent of all good seed; fraction 2 contained another 30 percent. With such a lot, the nurseryman could, by discarding all but fraction 1, retain two-thirds of all good seeds in 16 percent of the volume and 21 percent of the weight of the original lot. The seeds put into the beds would run almost 80 percent full, assuming no losses in storage or

Table 2. – *Seed weights and distribution of full seeds by fraction. The 4th fractions of both lots were only 1 percent full and were omitted from table*

Aspirator fractions	Weight of 500 seeds	Total seeds	Total full seeds	Proportion of lot's full seeds
	Gram	*Number*	*Number*	*Percent* [1]
Lot A				
1 (heaviest)	13.25	2,302	1,418	14
2	8.45	55,385	7,532	72
3	7.15	53,986	1,512	14
Total	. . .	111,673	10,462	100
Lot B				
1 (heaviest)	7.75	24,065	19,156	67
2	5.05	50,792	8,533	30
3	3.65	23,151	1,019	3
Total	. . .	98,008	28,708	100

[1] Based on an average of all cutting and germination tests.

stratification. Also, by retaining fraction 2, one could recover practically all of the remaining full seeds in less than half (46 percent) of the volume of the unprocessed lot.

Lot A, with only 9 percent full seeds, is a more typical yellow-poplar lot. By keeping only the heavy fraction of Lot A, the nurseryman would have seeds 60 percent full, but only 14 percent of the total filled seeds would be recovered. Fraction 2, while only 12 percent full, contains 72 percent of the full seeds. The logical step would be to run fraction 2 through the aspirator again, sacrificing a few good seeds to eliminate many empty ones. Fractions 1 and 2 together after a single cleaning contained only about one-third of the original weight and volume.

PILOT TEST

The processing method was tested on a pilot scale with seeds from State nurseries at Winona, Mississippi, and Pinson, Tennessee. These lots, described below, were composed of separated, air-dried carpels:

	Mississippi	*Tennessee*
Approximate volume (bushel)	40	20
Full seeds (percent)	10	6
Carpels per pound	52,700	46,300

Seeds were dewinged in batches in a large Clipper[4] debearder. Approximately 3 bushels of carpels were run at a time; 5 minutes were usually long enough to complete the dewinging. Wing fragments and other trash were removed in a large pneumatic aspirator.

The seeds were separated into five specific-gravity fractions with an Oliver Gravity Separator.[4] Percent fullness was determined by cutting three samples of 50 seeds from each fraction.

Germination was tested in a manner similar to that for the small lots. Germination blotter paper underlain with one layer of moist Kimpak was the medium. The test period was 45 days.

The lots were upgraded and their bulks were reduced considerably (table 3). Dewinging and cleaning removed between 50 and 60 percent of the original weight and volume. The heaviest fractions from both lots were about 64 percent full.

In the Tennessee lot approximately 90 percent of the filled seeds could be recovered in fractions 1, 2, and 3, a combination that contained only 9 percent of the original weight and 8 percent of the original volume. Blending of these three lots would result in a lot approximately 50 percent full.

[4] Mention of a trade name is to identify equipment used and does not constitute endorsement by the U. S. Department of Agriculture or Mississippi State University.

Table 3. — *Characteristics of original lots and separated fractions in pilot scale test*

Lot component	Total weight	Proportion of original weight	Total volume	Proportion of original volume	Proportion of filled seeds	Germinative capacity of full seeds
	Pounds	*Percent*	*Bushels*	*Percent*	*Percent*	*Percent*
			TENNESSEE			
Intact seeds	175	100	20	100	6	26
Dewinged and cleaned	76	43	8	40	6	50
Density fractions						
1 (heaviest)	9	5	½	2	65	55
2	2	1	¼	1	48	52
3	6	3	1	5	28	60
4	10	6	1	5	4	60
5 (lightest)	50	29	5	25	0	------
			MISSISSIPPI			
Intact seeds	420	100	40	100	10	78
Dewinged and cleaned	168	40	19	48	10	76
Density fractions						
1 (heaviest)	24	6	1¼	3	64	62
2	29	7	3	8	16	87
3	16	4	2¼	6	4	88
4	66	16	7½	19	5	87
5 (lightest)	32	8	4½	11	4	100

In the Mississippi lot the percent of filled seeds dropped sharply in the lighter fractions. An estimate by weight indicated that 75 to 80 percent of all filled seeds were in the two heaviest fractions, which comprised only 13 percent by weight and 11 percent by volume of the original lot. A combination of fractions 1 and 2 would be about 38 percent full.

Results of the germination tests indicated that processing did not damage the seeds (table 3). This conclusion is based mainly on the germinative capacity of seeds with intact carpels vs. dewinged and cleaned seeds. Germination was lower in the Tennessee seeds than in the Mississippi lots. This difference may reflect a greater chilling requirement in stratification for the more northern sources.

The Mississippi seeds were returned to the Mississippi Forestry Commission and planted in drills in the spring of 1970 at the Winona Nursery. Germination and early growth were very uniform.

DISCUSSION AND CONCLUSIONS

The upgrading method described is practical. Modifications could be made in many extractories, but the basic steps of dewinging, cleaning, and separating are essential. Continous-flow processing is more desirable than batch processing, of course, and the dewinged and rounded yellow-poplar seeds have good flow characteristics. Time needed for good dewinging in the debearder varied by lot. Carpel characteristics and moisture content were the main causes of such variation, and the machine operator's judgment must always be relied upon to produce uniformly dewinged seeds.

The large aspirator very efficiently removed all but large trash, such as cone axes and partially intact cones. Air-screen cleaners would probably remove this large trash, as well as light trash and dust.

There is considerable latitude in the proportion of filled seeds that are obtained. Almost all filled seeds can be recovered through repeated separation of medium and heavy fractions. In choosing goals, the seed processor should consider the amount of seed on hand, original fullness, and processing costs.

SOUTHERN FOREST EXPERIMENT STATION

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COTTONTAIL RABBITS CLIP YOUNG LONGLEAF PINE SEEDLINGS

T. E. Campbell [1]

SOUTHERN FOREST EXPERIMENT STATION

Cottontail rabbits (Sylvilagus floridanus) *often kill a major proportion of direct-seeded southern pine seedlings by clipping the newly germinated plants just above the groundline.*

Clipping of newly germinated seedlings has long been a problem in direct seeding southern pines in Louisiana. Losses are usually most serious for fall-sown longleaf pine *(Pinus palustris* Mill.); they typically range from 10 to 25 percent of a strand, but in some instances over half the seedlings have been destroyed.

The damage is easily recognized. Newly germinated seedlings are clipped off smoothly about ⅛ inch above the groundline, and all cotyledon tissue up to the attached seedcoat is consumed (fig. 1). The seedcoat is left undamaged, probably because of the repellent coating applied before direct seeding *(6)*. Most clipping occurs at night.

The extent of predation is difficult to predict. It varies in intensity from year to year,

Figure 1.—*Longleaf pine seedling clipped by cottontail rabbit.*

and a sharp boundary often delineates damaged and undamaged portions of a stand. Seedlings are clipped from December through March, but attacks are most common in January and early February, when other green vegetation is scarce in Louisiana. Depredations usually last for only a few days to 2 weeks, and when they cease many undamaged seedlings usually remain.

In a systematic attempt to identify the predator, a list of principal suspects was prepared. From this list, previously reported studies elim-

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inated short-tailed shrews *(Blarina brevicauda* and *Cryptotis parva) (1),* short-tailed crickets *(Anurogryllus muticus) (3),* and prairie crayfish *(Cambarus* spp.) *(4).* Three species of mice that are common on direct-seeded areas were eliminated in an unreported study. The mice were penned in outdoor enclosures and seedlings were exposed to them. The animals clipped a few newly germinated seedlings, but they ate the attached seedcoats and clipped the seedlings in a way different from that of the major predator.

Meanwhile, it was found that the animal responsible for major clipping losses could not or would not pass through 1-inch-mesh wire fencing 3 feet high. In addition, cottontail rabbit tracks were found around 11 clipped seedlings in a plowed furrow where the soil had been softened and blackened with organic matter by a rain the previous night.

Since most clipping is done after dark, about 20 night hunts were made on areas direct seeded with longleaf pine. Each lasted 2 to 4 hours with two or three men using headlights to carefully search for the predator. Some hunts were made in the rain, some on dark nights, and some on bright moonlit nights. Numerous rabbits were seen, indicating high populations at a time when heavy clipping losses were occurring. None were seen damaging seedlings even though many seedlings were clipped on nights of hunts. Five rabbits were killed with a shotgun and their stomach contents examined, but the results were inconclusive.

A detailed study of rabbits was made in a specially constructed enclosure measuring 9 × 18 feet. Sheet metal was nailed to wooden posts near the ground; the sides were raised to 5 feet in height and the top covered with 1-inch poultry netting. Then 14 trapped wild cottontails were observed two or three at a time for 40 days during an 80-day period. From 25 to 100 newly germinated seedlings were planted in the enclosure daily. A total of 1,600 seedlings were exposed. Every seedling was consumed each day, and without exception clipping was identical with that of the major predator.

Despite considerable efforts, rabbits were never seen or photographed clipping seedlings. A blind was built adjacent to the enclosure with a peep hole for an observer and a camera, but as long as an observer was in the blind the rabbits refused to eat. A portable photorecorder described by Dodge and Snyder *(5)* was set up in the field. Although clipping occurred within 30 feet of the camera, no seedlings on target spots were attacked. The low hum of the light receiver and the dim beam of red light from the machine may have frightened the rabbits. However, circumstantial evidence was enough to identify the predator.

Most damage caused by cottontail rabbits can be circumvented by direct-seeding longleaf pine in the spring *(2),* but there is some question about the ability of seedlings that germinate in February and March to survive a very dry summer. Clipping losses are greatest for fall-sown seedlings, and summer mortality is highest for spring-sown longleaf seedlings. Perhaps the best procedure for offsetting damage is to sow enough seeds to withstand rabbit losses up to 25 percent. In a long series of observations, clipping losses seldom exceeded this figure.

LITERATURE CITED

1. Campbell, T. E.
   1970. *Blarina brevicauda* and *Cryptotis parva* do not damage longleaf pine cotyledons. Am. Midl. Nat. 84: 256-257.
2. Campbell, T. E.
   1970. Spring sowing of longleaf pine reduces risk of seedling clipping. J. For. 68: 658-659.
3. Campbell, T. E.
   1971. Pine seed and seedling depredations by short-tailed cricket. J. Econ. Entomol. (In press)
4. Campbell, T. E.
   1971. Prairie crayfish a hazard in direct seeding. USDA Forest Serv. Tree Plant. Notes. (In press)
5. Dodge, W. E., and Snyder, D. P.
   1960. An automatic camera device for recording wildlife activity. J. Wildl. Manage. 24: 340-342.
6. Mann, W. F., Jr.
   1970. Direct-seeding longleaf pine. USDA Forest Serv. Res. Pap. SO-57, 26 p. South. Forest Exp. Stn., New Orleans, La.

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YELLOW-POPLAR ROOT DEVELOPMENT ON HARTSELLS SUBSOILS

Nelson S. Loftus[1]

SOUTHERN FOREST EXPERIMENT STATION

First-year growth of yellow-poplar seedlings is satisfactory on Hartsells soils from Tennessee's Cumberland Plateau only when the A horizon is present. Root development is inhibited in the B2 horizon, probably because of Ca deficiency, A1 toxicity, or a combination of the two.

Survival of planted yellow-poplar (*Liriodendron tulipifera* L.) is good on a wide range of forest sites on Tennessee's Cumberland Plateau (*11*). However, growth variations have been noted within apparently similar soils. The concentration of roots in the surface horizons of some Hartsells soil profiles suggested that root development may be limited by subsoil properties, rather than total depth to bedrock. The preliminary study reported here evaluated yellow-poplar seedling growth and root development in surface and subsurface horizons of the Hartsells soil series.

PROCEDURES

Yellow-poplar seedlings were grown in undisturbed samples taken from 10 Hartsells soil profiles under mixed oak-hickory stands near Sewanee, Tennessee. Cylindrical core samples 15 cm. in diameter and 18 cm. deep were extracted from the A, B21, and B22 horizons of each profile (*1*). In addition, three combinations, A + B21, A + B22, and B21 + B22, were formed by sampling the soil in such a way as to get the desired proportions of the A and B horizons. The A + B combinations were composed of 1/3 A horizon and 2/3 B horizon by volume; the B21 + B22 combination contained equal volumes of the two horizons.

Ten replications of the six horizon combinations were placed in a shadehouse in a randomized complete-block design. Twenty-five stratified, fungicide-treated seeds were sown on each sample in April 1969. Two months after germination the seedlings were thinned to leave three plants per can. Seedlings were watered alternately from above and below as needed.

After one growing season the seedlings were removed from the soil, root distribution within the soil mass was noted, shoot lengths were measured, and the lengths, ovendry weights, and numbers of roots were determined.

Soil analysis was confined to the single horizon samples (A, B21, and B22), which were air dried, crushed to pass a 2-mm. screen, and thoroughly mixed. Soil textures were determined by the Bouyoucos hydrometer method and bulk density was estimated from sample cores of undisturbed soil (*12*). Oxidizable organic matter was determined by the Walkley-Black method

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(*12*). Soil pH was measured with a glass electrode in a 1:1 soil-water mixture. Exchangeable K, Na, Ca, and Mg were extracted from the soil with 1.0 *N* neutral NH_4OAc. K and Na were determined with a Beckman DU flame spectrophotometer, Ca by oxalate precipitation with $KMnO_4$ titration, and Mg by phosphate precipitation with H_2SO_4 titration (*12*). Total acidity and KCl-extractable Al were measured by titration (*9*). Soil cation-exchange capacity (CEC) was calculated from the sum of exchangeable bases and total acidity. P was extracted with a dilute acid-fluoride solution (Bray No. 1) and determined colorimetrically (*8*). Total N was determined by the macro Kjeldahl procedure.

RESULTS AND DISCUSSION

Seedlings grew significantly taller (1-percent level) where some or all of the soil was from the A horizon (table 1). The B-horizon seedlings were stunted by comparison (fig. 1); the leaves did not fully develop and appeared chlorotic, and there was very little growth beyond that made during the first month after germination.

Previous work in the central States has also demonstrated the beneficial effects of the A horizon on yellow-poplar seedling growth (*2*). In New Hampshire, similar results were obtained with yellow birch in a Podzol soil (*6*). In northern Georgia, thickness of the A2 horizon and its organic-matter content influenced yellow-poplar growth (*7*), and properties of the A horizon strongly affected growth of older stands of yellow-poplar in the Piedmont of southern Virginia and the Carolinas (*3*).

In the present study, root development in material from A and A + B horizons differed from that in B-horizon material in the same way as height growth (fig. 2). There was no difference in taproot length or in the number and cumulative length of the primary lateral roots of seedlings grown in the A and A + B samples (table 1). Roots in both these media were significantly longer, more numerous, and heavier than those in the B-horizon material.

Although there was no statistically significant difference in root measurements between the A-horizon samples and the A + B combinations, there was a notable difference in root distribution within the soil masses (fig. 3). The root systems of seedlings grown in the A-horizon samples were well distributed throughout the soil, with good lateral branching and a healthy appearance. In contrast, approximately 90 percent of the roots in the A + B combinations were concentrated in the A horizon or upper 1/3 of the soil volume. Many of the roots that penetrated the B horizon of the combination were weak, discolored, and appeared to be decomposing. In the B21 + B22 combination, the roots were primarily concentrated in the B21 horizon and appeared necrotic at the tips. These observations suggest that in addition to the more favorable growing conditions of the A horizon there may have been something harmful in the subsoil.

Bulk density of the A horizon was significantly lower than those of the B21 and B22 horizons (table 2). In all samples the lengths, weights, and numbers of roots decreased in the higher bulk density of the B horizons. Bulk density is probably not a major cause for poor growth in these subsoils, however. First, taproots pene-

Table 1. – *First-year shoot and root growth of yellow-poplar seedlings in various horizons of a Hartsells soil*

Horizons present	Seedling height	Taproot length	Primary lateral roots		Ovendry weight	
			Cumulative length	Number	Roots	Stems
	Cm.				Mg.	
A	15.2 a[1]	16.7 a	210.5 a	32 a	1,037 a	507 a
1/3 A + 2/3 B21	12.8 a	17.9 a	187.9 a	27 a	781 a	350 a
1/3 A + 2/3 B22	13.9 a	17.1 a	205.5 a	29 a	731 a	415 a
B21	4.4 b	12.7 b	63.1 b	18 b	113 b	44 b
B22	4.0 b	11.8 b	57.7 b	14 b	73 b	31 b
1/2 B21 + 1/2 B22	4.1 b	12.1 b	65.0 b	17 b	72 b	31 b

[1] In individual columns, values followed by the same letter do not differ significantly at the 0.01 level.

Ca, K, P, and N, all of which are essential for plant growth. The low level of Ca in these subsoils is of particular significance since it is required for root growth and can not be translocated from one part of the root system to another.

In the subsoil, the relatively high extractable acidity and the correspondingly low (less than 20 percent) base saturation were also unfavorable. Since soil reaction and the concentration of exchangeable hydrogen varied very little between horizons, pH *per se* was probably not responsible for the inhibited root growth. On the other hand, concentrations of KCl-extractable Al increased from an average of 1.5 meq./100g. of soil in the A horizon to 2.8 meq./100g. in the B21 and 3.4 meq./100g. in the B22. At the same time, Ca decreased from an average of 1.2 meq./100g. in the A horizon to less than 0.2 meq./100g. in the subsoil. Thus it is possible that in the presence of a sufficient supply of available nutrients, especially Ca, the high concentration of Al in the A horizon was of minor importance to root growth. Conversely, a complex of multiple nutrient deficiencies and increased levels of Al in the subsoil may have inhibited root growth and interfered with nutrient uptake.

Although the sensitivity of yellow-poplar to Al is not known, even low concentrations of this element in acid soils can inhibit root growth in cotton (*10*). In a study of toxic factors in acid soils, excess Al caused cotton plants to wilt, and decreased the uptake of Ca, P, and K (*4*). Other investigators have reported that the combination of Ca deficiency and Al at toxic concentrations inhibits the penetration of subsoils by cotton roots (*5*).

LITERATURE CITED

1. Clark, F. B.
   1961. Pot culture—an aid to site evaluation. Ind. Acad. Sci. Proc. 70: 234-237.

2. Clark, F. B., and Losche, C. K.
   1969. Importance of the A horizon in hardwood seedling establishment. J. For. 67: 504-505.

3. Della-Bianca, L., and Olson, D. F., Jr.
   1961. Soil-site studies in Piedmont hardwood and pine-hardwood upland forests. Forest Sci. 7: 320-329.

4. Foy, C. D., and Brown, J. C.
   1963. Toxic factors in acid soils: 1. Characterization of aluminum toxicity in cotton. Soil Sci. Soc. Am. Proc. 27: 403-407.

5. Howard, D. D., and Adams, F.
   1965. Calcium requirement for penetration of subsoils by primary cotton roots. Soil Sci. Soc. Am. Proc. 29: 558-562.

6. Hoyle, M. C.
   1965. Growth of yellow birch in a Podzol soil. USDA Forest Serv. Res. Pap. NE-38, 14 p. Northeast. Forest Exp. Stn., Upper Darby, Pa.

7. Ike, A. F., Jr., and Huppuch, C. D.
   1968. Predicting tree height growth from soil and topographic site factors in the Georgia Blue Ridge Mountains. Ga. Forest Res. Counc. Res. Pap. 54, 11 p.

8. Jackson, M. L.
   1958. Soil chemical analysis. 498 p. Englewood Cliffs, N. J.: Prentice-Hall, Inc.

9. McLean, E. O.
   1965. Aluminum. *In* Methods of soil analysis, p. 978-998. Part 2. Am. Soc. Agron., Madison, Wisc.

10. Rios, M. A., and Pearson, R. W.
    1964. The effect of some chemical environmental factors on cotton root behavior. Soil Sci. Soc. Am. Proc. 28: 232-235.

11. Russell, T. E., Loftus, N. S., Mignery, A. L., and Smalley, G. W.
    1970. Planting yellow-poplar in central Tennessee and northern Alabama. USDA Forest Serv. Res. Pap. SO-63, 17 p. South. Forest. Exp. Stn., New Orleans, La.

12. USDA Soil Conservation Service.
    1967. Soil survey laboratory methods and procedures for collecting soil samples. Soil Surv. Invest. Rep. 1, 50 p.

13. Veihmeyer, F. J., and Hendrickson, A. H.
    1948. Soil density and root penetration. Soil Sci. 65: 487-493.

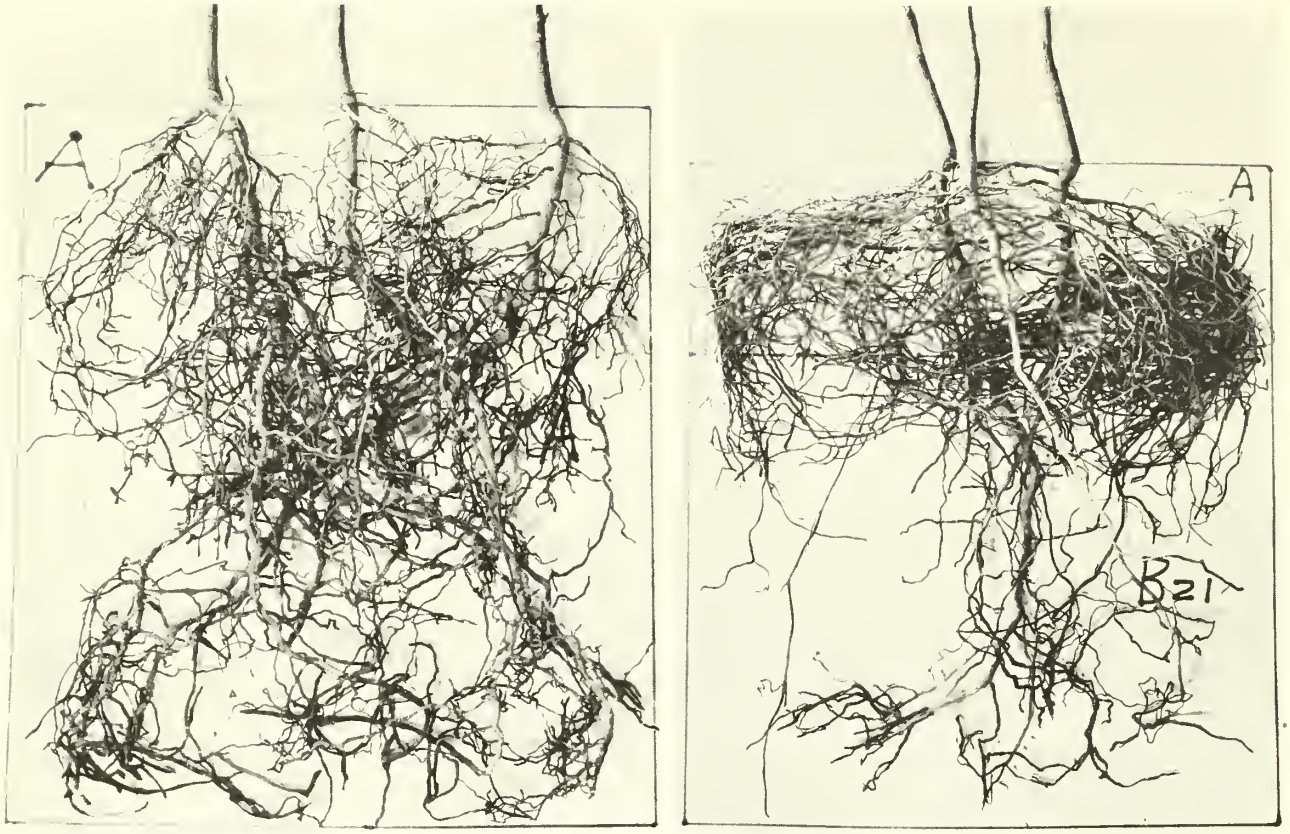

Figure 3.—*Distribution of roots of yellow-poplar seedlings in a Hartsells soil:* Left, *A horizon;* right, *1/3 A horizon and 2/3 B21.*

Table 2. – *Some physical properties of selected Hartsells soil horizons*

Soil horizon	Bulk density	Organic matter	Sand	Silt	Clay
	G./cc.		Percent		
A	1.19	2.4	50.2	30.4	19.4
B21	1.40	.5	45.6	29.0	25.4
B22	1.52	.2	48.6	25.0	26.4

trated the B horizons in all cases. Second, bulk densities ranged from 1.33 to 1.62 and averaged 1.40 and 1.52 for the B21 and B22 horizons, respectively. All values were lower than the 1.75 reported as restrictive in coarse-textured soils (*13*).

Porosity of the subsoil averaged around 40 percent, which should be sufficient for normal root development. Texture varied only slightly, ranging from a loam in the A horizon to a sandy clay loam in the B22; the majority of the samples were classified as loams. These textures have been reported to be favorable for the growth of yellow-poplar (*7*).

Soil chemical analysis and good seedling growth indicated that nutrient levels within the A horizon were sufficient for establishing yellow-poplar from seed (table 3). In contrast, the B horizons were practically devoid of

Table 3. – *Chemical properties of selected Hartsells soil horizons*

Property	Soil horizon		
	A	B21	B22
Extractable bases	MEG./100 GRAMS		
Ca	1.18	0.19	0.14
Mg	.22	.23	.33
K	.64	.14	.13
Na	.20	.10	.10
Extractable acidity	1.98	3.19	3.90
CEC	4.22	3.85	4.60
Extractable A1	1.54	2.81	3.45
pH	4.9	4.9	5.0
		P.P.M.	
Extractable P	17.7	3.7	2.8
		PERCENT	
Total N	.09	.04	.04
Base saturation	53	17	15

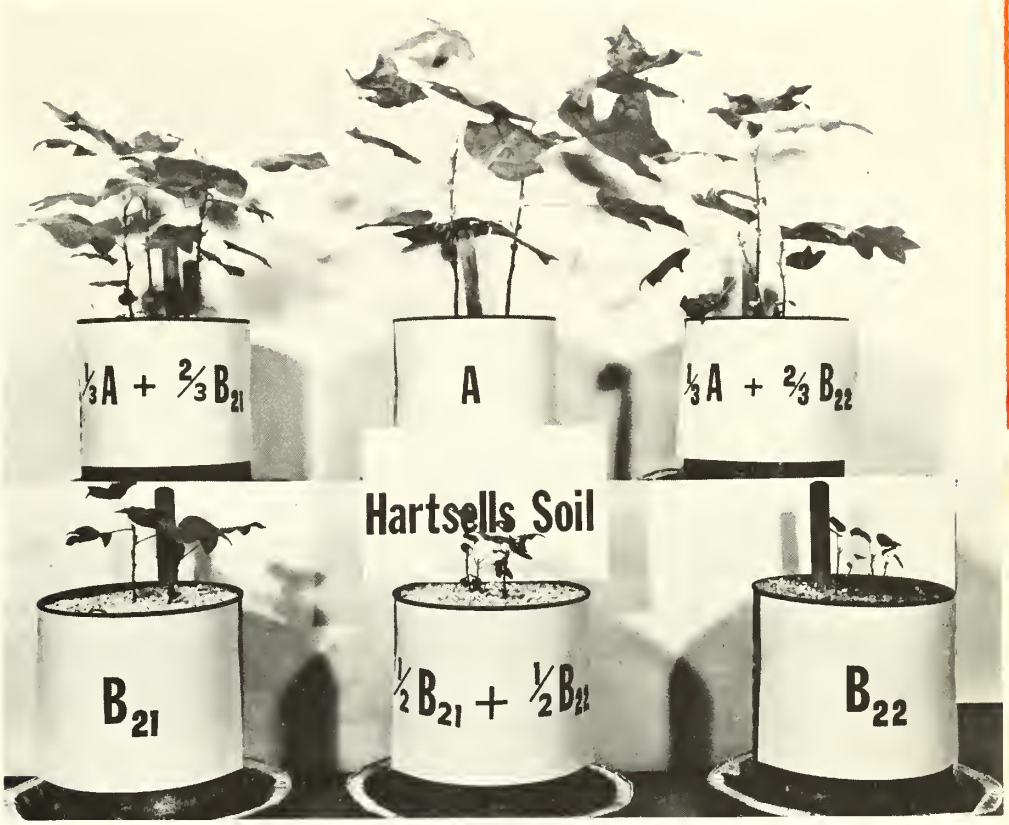

Figure 1. — *Growth of yellow-poplar seedlings after one growing season in various horizons of a typical Hartsells soil.*

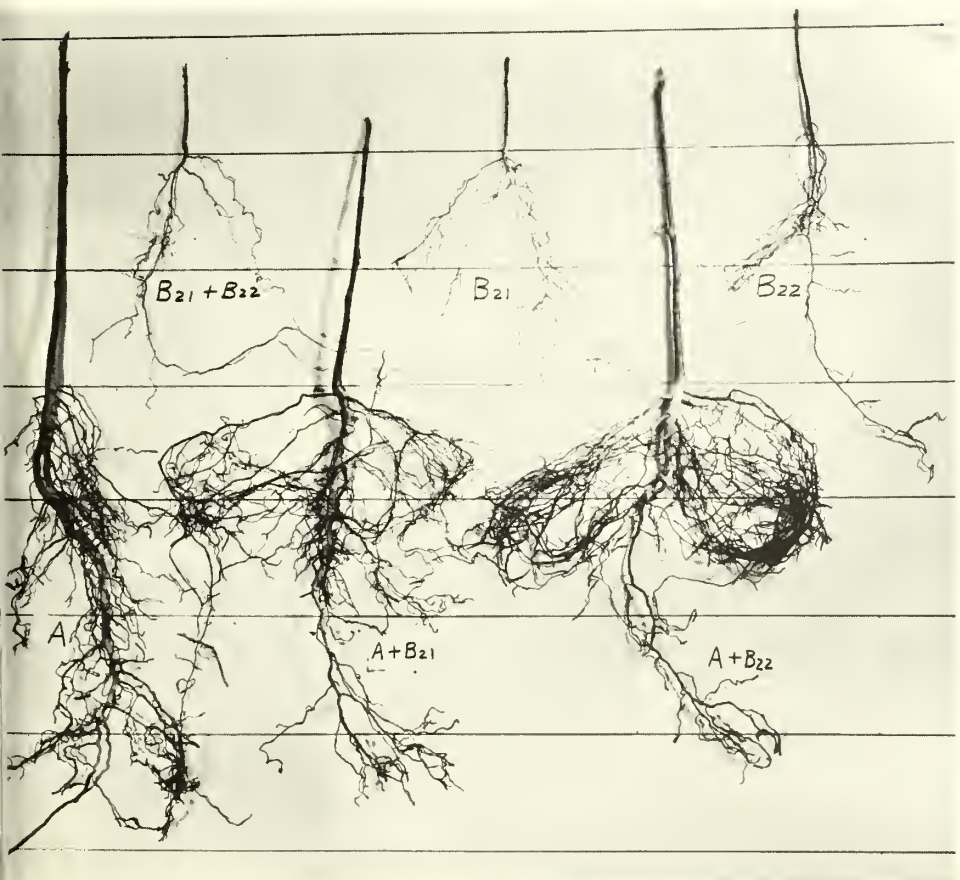

Figure 2. — *Root development of yellow-poplar seedlings after one growing season in various horizons of a typical Hartsells soil.*

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LARGE PLANTING HOLES NOT NEEDED FOR COTTONWOOD CUTTINGS AND SEEDLINGS IN MISSISSIPPI DELTA

B. G. Blackmon[1]

SOUTHERN FOREST EXPERIMENT STATION

On Commerce silt loam and Sharkey clay in the Mississippi Delta, 20-inch and 32-inch cuttings and seedlings of Populus deltoides *Bartr. planted in holes 9 inches in diameter survived and grew no better than 20-inch cuttings planted in holes 3/4 inch in diameter.*

Eastern cottonwood (*Populus deltoides* Bartr.) is commonly planted by inserting a cutting 18 inches into a subsoil slit or a hole 3/8 to 3/4 inch in diameter. When properly executed, these methods usually are highly successful in the South (*3*). Many foresters, however, have speculated that planting in deep, large-diameter holes might improve survival and early growth. In Europe, Jobling (*1*) recommended planting rooted poplar cuttings in holes at least 18 inches square and from 15 to 24 inches deep. Kaszkurewicz (*2*), in Louisiana, obtained greater survival and height growth from 40-inch cuttings planted 30 inches deep in holes 9 to 18 inches in diameter than from 20-inch cuttings planted in holes measuring 16 inches by 1 inch. Minckler and Woerheide (*4*) also recommended planting cottonwood seedlings in auger holes.

In the study reported here performance of cottonwood seedlings and cuttings planted in large-diameter holes was compared with that of cuttings planted in small-diameter holes.

METHODS

The study was installed on two sites, a Commerce silt loam north of Greenville, Mississippi, and a Sharkey clay near Stoneville, Mississippi. Vegetation had recently been sheared from the silt loam soil. Cottonwood grows considerably faster on Commerce than on Sharkey soil.

Both sites were prepared by thorough disking, and planting was done in March 1967, 1968, and 1969. Cuttings 20 inches long were placed in holes made 18 inches deep and 3/4 inch in diameter with a planting rod. Auger holes 9 inches in diameter and 18 and 30 inches deep were made to accommodate cuttings and seedlings 20 and 32 inches long. There were five planting treatments (table 1).

Each year planting treatments were replicated three times in a randomized complete block design on each site. Plots consisted of three rows of 10 planting spots spaced 9 by 9 feet. All 30 planting spots on each plot were included in survival tallies, but only interior trees were measured to determine growth.

[1] The author is Soil Scientist at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Miss., by the Southern Forest Experiment Station, USDA Forest Service, in cooperation with the Mississippi Agricultural & Forestry Experiment Station and the Southern Hardwood Forest Research Group.

Table 1. — *Average total heights of trees from cuttings and seedlings planted on Commerce silt loam*

Year of planting and treatment	Total height in November		
	1967	1968	1969
	FEET		
1967			
20-inch cutting, ¾-inch hole	11	26	34
20-inch cutting, 9-inch hole	11	25	34
32-inch cutting, 9-inch hole	11	25	34
20-inch seedling, 9-inch hole	11	24	33
32-inch seedling, 9-inch hole	12	26	31
Average	11.2	25.4	33.2
1968			
20-inch cutting, ¾-inch hole	....	12	26
20-inch cutting, 9-inch hole	....	12	25
32-inch cutting, 9-inch hole	....	12	25
20-inch seedling, 9-inch hole	....	12	23
32-inch seedling, 9-inch hole	....	12	25
Average	....	12.0	24.8
1969			
20-inch cutting, ¾-inch hole	....	....	11
20-inch cutting, 9-inch hole	....	....	11
32-inch cutting, 9-inch hole	....	....	10
20-inch seedling, 9-inch hole	....	....	11
32-inch seedling, 9-inch hole	....	....	11
Average	....	....	10.8

Table 2. — *Average total heights of trees from cuttings and seedlings planted on Sharkey clay*

Year of planting and treatment	Total height in November		
	1967	1968	1969
	FEET		
1967			
20-inch cutting, ¾-inch hole	5	13	17
20-inch cutting, 9-inch hole	5	14	18
32-inch cutting, 9-inch hole	6	15	19
20-inch seedling, 9-inch hole	5	14	18
32-inch seedling, 9-inch hole	6	13	18
Average	5.4	13.8	18.0
1968			
20-inch cutting, ¾-inch hole	....	8	13
20-inch cutting, 9-inch hole	....	8	13
32-inch cutting, 9-inch hole	....	8	12
20-inch seedling, 9-inch hole	....	8	14
32-inch seedling, 9-inch hole	....	7	12
Average	....	7.8	12.8
1969			
20-inch cutting, ¾-inch hole	....	....	6
20-inch cutting, 9-inch hole	....	....	6
32-inch cutting, 9-inch hole	....	....	5
20-inch seedling, 9-inch hole	....	....	6
32-inch seedling, 9-inch hole	....	....	6
Average	....	....	5.8

The plantations were maintained relatively free of weeds by disking during the first two growing seasons. Total heights of survivors were measured in November 1967, 1968, and 1969. Statistically significant differences among treatment means at the 0.05 level were identified by Duncan's multiple range test.

RESULTS

Height growth was not significantly influenced by treatment, and the ranking of heights by treatment changed from year to year (tables 1 and 2).

First-year height growth was significantly better in the 1968 planting than in the other two plantings. Weather records at Stoneville indicate 23.0 inches of rainfall during May through September of 1968, compared to 12.9 for the same period in 1967 and 13.6 in 1969. There were no significant differences in second-year heights.

Survival ranged from 80 to 100 percent, with no relationship to year of planting or treatment.

These results indicate that planting in an auger hole is not advantageous on the sites tested. Auger holes are more expensive to make than rod holes and they are no better. Most industrial planters insert cuttings into a subsoil slit, which presumably is as good as rod or auger holes and is even more economical.

There are probably some sites on which auger-hole planting would be advantageous. On severely compacted, medium-textured, old-field sites, growth or survival could conceivably be improved by placing cuttings in auger holes. However, until research or experience indicates otherwise, there appears to be no reason to abandon present techniques for planting eastern cottonwood on most sites in the Mississippi Delta.

LITERATURE CITED

1. Jobling, J.
   1963. Poplar cultivation. G. B. For. Comm. Leafl. 27, rev., 26 p.

2. Kaszkurewicz, A.
   1967. Research in planting bottomland hardwoods: A progress report. La. State Univ. Sch. For. and Wildl. Manage., LSU For. Notes 72, 4 p.

3. McKnight, J. S.
   1970. Planting cottonwood cuttings for timber production in the South. USDA Forest Serv. Res. Pap. SO-60, 17 p. South. Forest Exp. Stn., New Orleans, La.

4. Minckler, L. S., and Woerheide, J. D.
   1965. One way to establish cottonwood plantations—a case history. South. Lumberman 211(2632): 177-178.

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AIDS FOR SCREENING REGRESSIONS WITH "REX" PROGRAM

Robert L. Bailey[1]

SOUTHERN FOREST EXPERIMENT STATION

Two tables and a short computer program can greatly assist in determining the number of regressions generated in all possible combinations by Grosenbaugh's REX program.

The computer program REX[2] written in FORTRAN IV is primarily designed for combinatorial screening of multiple regressions. The facility to combine variables into sets and sets into groups makes the program very powerful for examining large numbers of nonfixed regressions. However, the user is faced with the complicated problem of determining whether the number of generated regressions will exceed the allowable limit.

If NY is the number of dependent variables, NXX the total number of independent variables to be examined, and NGX the number of groups of independent variables, three restrictions built into REX are:

(1) $NY \leqslant 8$

(2) $NY + NXX \leqslant 50$

(3) $NGX \leqslant 17$.

In addition, the total number of generated regressions (LGK) must not exceed a quantity (LPP), which is a function of NY and the computer capacity. For REX on 32K word computers, LPP is 16,400 divided by NY+1. On 280K word computers, LPP becomes 262,200 divided by NY+1.

Due to the options for specifying groups and sets, calculating LGK can be very difficult. However, if each group has only a single set,

$$LGK = \sum_{J=1}^{LM} \begin{bmatrix} NGX \\ J \end{bmatrix} , \qquad (1)$$

where NGX = number of groups,

LM = maximum number of groups allowed to be represented in any regression,

$$\begin{bmatrix} NGX \\ J \end{bmatrix} = \frac{NGX!}{J!\,(NGX-J)!} ,$$

$$J! = (J)(J-1)\cdots(3)(2)(1) ,$$

and $0! = 1$.

Equation (1) can be evaluated for specific values of LM and NGX using a table of binomial coefficients. Tables 1 and 2 generated with equation (1) provide threshold values for NY, NGX, and LM with $1 \leqslant NY \leqslant 8$ and $1 \leqslant NGX \leqslant 17$.

If some groups have more than one set, equation (1) will not correctly determine LGK. One obvious solution in this situation is to let REX determine the number of

[1] The author is Mathematical Statistician with the Southern Forest Experiment Station's Biometrics Services unit.

[2] Grosenbaugh, L. R. REX – FORTRAN-4 system for combinatorial screening or conventional analysis of multivariate regressions. USDA Forest Serv. Res. Pap. PSW-44, 47p. Pac. Southwest Forest & Range Exp. Stn., Berkeley, Calif. 1967.

Table 1. — *Maximum number of groups represented in any regression (LM), such that the number of generated regressions (LGK) does not exceed 16,400/(NY+1)*

Number of groups (NGX)	Number of dependent variables (NY)							
	1	2	3	4	5	6	7	8
	NUMBER							
[1]10	10	10	10	10	10	10	10	10
11	11	11	11	11	11	11	11	7
12	12	12	12	6	6	5	5	5
13	13	6	6	5	5	4	4	4
14	6	5	5	4	4	4	4	4
15	5	5	4	4	4	4	4	3
16	5	4	4	4	4	3	3	3
17	4	4	4	4	3	3	3	3

[1]For NGX < 10, LM=NGX.

Table 2. — *Maximum number of groups represented in any regression (LM) such that the number of generated regressions (LGK) does not exceed 262,200/(NY+1)*

Number of groups (NGX)	Number of dependent variables (NY)							
	1	2	3	4	5	6	7	8
	NUMBER							
[1]14	14	14	14	14	14	14	14	14
15	15	15	15	15	15	15	15	9
16	16	16	16	9	8	7	7	7
17	17	8	8	7	7	6	6	6

[1]For NGX < 14, LM=NGX.

generated regressions. A sequence of dummy problems can be set up with one blank data card to investigate alternatives. However, a more reasonable approach for the user with access to a small core storage conversational computer terminal and faced with relatively slow turnaround on REX jobs is to make the determination himself. REXAID, the short program in figure 1 patterned after a segment of subroutine PALM in REX, was developed for these circumstances. It is written in FORTRAN for the GE 440 time-share system but could easily be modified or converted to Basic or CPS.

Inputs to the program are NGX and an array NG(17) containing the number of sets in each group. The program checks for

$$\sum_{i=1}^{NGX} NG(i) = NXS \leqslant 30 \text{ and } NGX \leqslant 17$$

and loops with NY=1 to 8 in steps of 1. At each iteration, allowable values for NXX and LM are printed. The listing shown is for the 32K version of REX. To

```
      DIMENSIØN NG(17),C(17),SC(17),NV(17),KNT(17)
      DATA IN,IØUT/0,66/
      PRINT=1
    1 IF(PRINT) 3,2,3
    3 WRITE(IØUT,100)
  100 FØRMAT(5X,"NØW ENTER NUMBER ØF GRØUPS, NGX."/
     &   "ENTER A ZERØ IF YØU ARE FINISHED.")
    2 READ, NGX
      IF(NGX) 13,13,7
    7 IF(NGX-17) 24,24,25
   25 WRITE(IØUT,1005)
 1005 FØRMAT(5X,"NGX CANNØT EXCEED 17 IN REX.  TRY ",
     &   "AGAIN."//)
      GØ TØ 1
   24 CØNTINUE
      IF(PRINT) 5,4,5
    5 WRITE(IØUT,101)
  101 FØRMAT(5X,"NØW ENTER THE NUMBER ØF SETS IN EACH ",
     &   "GRØUP"/"INTØ THE ARRAY NG(17).  IF NGX IS LESS ",
     &   "THAN 17,"/"ENTER ZERØS INTØ THE LAST 17-NGX ",
     &   "PLACES."/"ALL ENTRIES IN FREE FØRMAT WITH CØMMAS",
     &   " BETWEEN."/"TØ SUPPRESS THESE MESSAGES, STØP ",
     &   "EXECUTIØN AND"/"CHANGE LINE 120 TØ:  '120  PRINT=0",
     &   "'  .")
    4 READ,NG
      WRITE(IØUT,102) (NG(KK),KK=1,NGX)
  102 FØRMAT(/////10X,"SETS PER GRØUP FØR THIS PRØBLEM"/
     &   3(15X,613//))
      NXS=0
      DØ 28 L=1,NGX
   28 NXS=NXS+NG(L)
      IF(NXS-30) 30,30,29
   29 WRITE(IØUT,107) NXS
  107 FØRMAT(//5X,"NUMBER ØF NØN-FIXED SETS IS",I3,
     &   " .  MUST NØT EXCEED 30.")
      GØ TØ 1
   30 WRITE(IØUT,104)
  104 FØRMAT(//16X,"MAXIMUM VALUES FØR:"/16X,"NY",7X,
     &   "NXX",5X,"LM")
      DØ 6 NY=1,8
      LPP=16400/(NY+1)
      NXX=50-NY
      DØ 19 LM=1,NGX
      RGK=0.
      DØ 8 I=1,NGX
      C(I)=NG(I)
      SC(I)=C(I)
      RGK=RGK+SC(I)
      NV(I)=1
    8 KNT(I)=0
      KQ=NGX-1
    9 J=1
   10 DØ 11 I=J,KQ
      IF(KNT(I)) 11,12,11
   12 KNT(I)=1
      GØ TØ 14
   11 KNT(I)=0
      GØ TØ 15
   14 IN=NGX-I
      IM=IN+1
      KC=NV(IM)-LM
      IF(KC) 17,16,17
   16 J=I
      GØ TØ 10
   17 DØ 18 I=IM,NGX
      SC(I)=SC(IN)*C(I)
      RGK=RGK+SC(I)
   18 NV(I)=NV(IN)+1
      GØ TØ 9
   15 IRGK=RGK
      IF(IRGK-LPP) 19,20,20
   19 CØNTINUE
   20 LM=LM-1
      IF(LM) 6,6,21
   21 WRITE(IØUT,103) NY,NXX,LM
  103 FØRMAT(15X,I3,7X,I3,4X,I3)
    6 CØNTINUE
      WRITE(IØUT,105)
  105 FØRMAT(/////)
      GØ TØ 1
   13 STØP
      END
```

Figure 1.--*Listing of REXAID.*

modify for the 280K version, the constant 16,400 in line 500 must be changed to 262,200.

Three sample outputs are given in figure 2.

A. *Initial run with all explanatory messages.*

```
     NØW ENTER NUMBER ØF GRØUPS, NGX.
ENTER A ZERØ IF YØU ARE FINISHED.
INPUT:00170
 ?  11

     NØW ENTER THE NUMBER ØF SETS IN EACH GRØUP
INTØ THE ARRAY NG(17).  IF NGX IS LESS THAN 17,
ENTER ZERØS INTØ THE LAST 17-NGX PLACES.
ALL ENTRIES IN FREE FØRMAT WITH CØMMAS BETWEEN.
TØ SUPPRESS THESE MESSAGES, STØP EXECUTION AND
CHANGE LINE 120 TØ:  '120  PRINT=0'  .
INPUT:00340
 ? 3,3,4,5,2,1,3,2,1,1,1,0,0,0,0,0,0

          SETS PER GRØUP FØR THIS PRØBLEM
                3  3  4  5  2  1

                3  2  1  1  1

               MAXIMUM VALUES FØR:
               NY       NXX     LM
                1        49      3
                2        48      3
                3        47      3
                4        46      3
                5        45      3
                6        44      3
                7        43      2
                8        42      2
```

B. *Run with messages suppressed.*

```
120     PRINT=0

INPUT:00170
 ? 5

INPUT:00340
 ? 5,5,5,5,5,0,0,0,0,0,0,0,0,0,0,0,0

          SETS PER GRØUP FØR THIS PRØBLEM
                5  5  5  5  5

               MAXIMUM VALUES FØR:
               NY       NXX     LM
                1        49      5
                2        48      4
                3        47      3
                4        46      3
                5        45      3
                6        44      3
                7        43      3
                8        42      3
```

C. *Run with messages suppressed showing check for NXS* $\leqslant$ *30.*

```
120     PRINT=0

INPUT:00170
 ? 5

INPUT:00340
 ? 10,5,10,10,10,0,0,0,0,0,0,0,0,0,0,0,0

          SETS PER GRØUP FØR THIS PRØBLEM
                10  5 10 10 10

     NUMBER ØF NØN-FIXED SETS IS 45.  MUST NØT EXCEED 30.
INPUT:00170
 ?
```

Figure 2.--*Sample output from REXAID.*

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ACCURACY OF ZEISS TELEMETER TELETOP AND BARR AND STROUD DENDROMETERS

David R. Bower [1]

SOUTHERN FOREST EXPERIMENT STATION

In a test of two instruments on loblolly pines in central Louisiana, dendrometer-based estimates of tree volume, surface, length, or sum of diameters did not differ significantly from estimates based on caliper measurements. Both dendrometers overestimated measured volume by about 1 percent. The Barr and Stroud was somewhat more precise than the Teletop.

In the study reported here, data from two optical dendrometers were compared with measurements taken by climbing. The instruments were a Zeiss Telemeter Teletop as modified by Mesavage (1969a) and a Barr and Stroud model FP 15.[2] Though the modified Teletop is still under development, it promises to be economical in cost and convenient in operation, and it reads diameters directly.

MEASUREMENTS

Five 12-inch and five 14-inch d.b.h. loblolly pines were selected for measurement. The trees ranged from 12.9 to 18.5 inches in diameter outside bark at the stump. Diameter outside bark was measured with steel calipers and with diameter tape to 0.1 inch at stump height, at d.b.h., and (from a ladder) at three to six positions above d.b.h.—usually at 8-foot height increments—up to the base of the crown. The points at which diameter was measured were clearly marked, as was the aspect at which caliper measurements were taken. Cumulative height from stump to each diameter measurement point was determined by tape to 0.1 foot.

Each of three observers then measured the 10 trees with the Barr and Stroud dendrometer (Mesavage 1969b) and with a modified Tele-

[1] The author is Forest Biometrician with the Weyerhaeuser Research Center at Centralia, Washington. When the research was conducted, he was with the Southern Forest Experiment Station at New Orleans, La. Theodore V. Lacher, Southern Region, USDA Forest Service, and the late Clement Mesavage, Division of Timber Management, National Forest System, aided in the dendrometry. The staff of the Kisatchie National Forest aided in selecting the trees and measured the upper stems with calipers and tape.

[2] Mention of the instruments is for information only, and does not imply endorsement by the U. S. Department of Agriculture.

top. All data were processed by the STX program (Grosenbaugh 1967) via a subroutine devised for the Teletop (personal communication, L. R. Grosenbaugh, USDA Forest Service, Atlanta, Ga.).

Since the number of measurement points varied between trees, the average difference between dendrometer and caliper for a particular tree was used in statistical analyses. Differences between dendrometer and caliper were computed for average section volume, surface area, length, and sum of diameters for the entire tree and for the entire tree less the stump measurement. Statistical significance was tested at the 0.05 level.

RESULTS

Analysis of variance showed no differences between observers, size of tree, or instruments. There were no significant interactions. Larger trees had larger variance as indicated by chi-square test, but separate analyses on small and large trees revealed no significant differences due to observer or instrument.

Within-tree variation was larger for the Teletop than for the Barr and Stroud. An estimate of precision is given by the coefficient of variation (CV) of the caliper/dendrometer ratios for volume, surface, length, and sum of diameters (table 1). Between observers, the CV of diameters ranged from 0.86 to 0.89 for the Barr and Stroud and from 0.96 to 1.56 for the Teletop. Relative variability was somewhat greater for total tree length, with the range in CV being 1.22 to 1.66 for the Barr and Stroud and 1.94 to 2.90 for the Teletop. Relative variability was higher again for total tree surface area than for length, and higher for total cubic-foot volume than for surface area (table 1). In each case, the Teletop ratios were more variable than the Barr and Stroud ratios. Where the stump was excluded, relative variability was commonly increased rather than decreased. This result was contrary to expectations, since diameter changes rapidly at the point of stump measurement. It is possible that the low angle of inclination of the instrument and the good visibility of the stump rendered the readings highly accurate.

Table 1.—*Coefficient of variation of ratios of caliper/dendrometer estimates*

Instrument and observer	Volume	Surface area	Length	Sum of diameters
		TOTAL TREE		
Barr and Stroud				
B	2.83	1.71	1.28	0.89
L	2.14	1.42	1.22	.86
M	2.38	1.83	1.66	.89
Teletop				
B	4.41	3.39	2.90	1.56
L	3.51	2.61	1.94	1.08
M	3.00	2.56	2.57	.96
		TOTAL TREE LESS STUMP		
Barr and Stroud				
B	2.71	1.44	1.10	.99
L	2.26	1.69	1.71	1.26
M	2.82	1.96	1.68	1.22
Teletop				
B	5.08	3.86	3.12	1.30
L	4.29	3.12	2.31	1.44
M	3.04	2.36	2.45	1.16

CV values were larger when ratios were based on individual diameters or on individual bolts within a tree than when based on the whole tree or on averages for all bolts per tree. On a within-tree basis, the CV of dendrometer/caliper diameter estimates was 1.8 percent for the Barr and Stroud and 2.0 percent for the Teletop. The ratios for length were 9.0 and 9.5 percent for Barr and Stroud and Teletop, respectively, and 9.4 and 9.9 percent for cubic volume.

Finally, it is possible to compare both dendrometers directly with caliper and tape measurements. Table 2 shows the estimated mean tree volume, surface area, length, and sum of diameters for the Barr and Stroud, Teletop, and caliper measurements. If it is assumed that caliper measurements approximate true diameters, average total tree volume was overestimated by about 1 percent for both instruments. One observer using the Teletop underestimated caliper volume, and the other two observers overestimated. All three overestimated with the Barr and Stroud. When the stump section was deleted, the overestimate was 1.3 percent for the Teletop and 1.0 percent for the Barr and Stroud. Surface area was overestimated with both instruments, while length was slightly underestimated. The sum of tree diameters was overestimated by both instruments and to a greater degree if the stump section was included. Source of the instruments' positive bias is unknown.

Table 2.—*Tree measurements by optical dendrometers and by calipers*

Instrument	Volume		Surface area		Length		Sum of DIB	
	Mean	Error	Mean	Error	Mean	Error	Mean	Error
	Cu. ft.	*Pct.*	*Sq. ft.*	*Pct.*	*Ft.*	*Pct.*	*In.*	*Pct.*
TOTAL TREE								
Barr and Stroud	29.5	1.03	112.8	0.45	35.2	−0.11	78.8	0.29
Teletop	29.5	1.03	112.8	.44	35.2	− .20	79.0	.61
Calipers	29.2	.	112.3	.	35.2	.	78.6	.
TOTAL TREE LESS STUMP								
Barr and Stroud	25.2	1.04	99.2	.47	31.7	− .16	62.8	.04
Teletop	25.3	1.28	99.4	.71	31.8	.	62.9	.04
Calipers	25.0	.	98.7	.	31.8	.	62.6	.

To conclude, it appears that the modified Teletop is not as precise as the Barr and Stroud dendrometer, but is its equal in accuracy. The differences in precision are slight, however, and the factors of projected lower cost, equivalent accuracy, and direct reading for diameter make the Teletop very competitive with the Barr and Stroud for trees up to 14 inches in diameter at breast height. Further tests should be made for larger trees.

LITERATURE CITED

Grosenbaugh, L. R.
1967. STX—FORTRAN-4 program for estimates of tree populations from 3P sample-tree-measurements. USDA Forest Serv. Res. Pap. PSW-13 Rev., 76 p. Pac. Southwest Forest and Range Exp. Stn., Berkeley, Calif.

Mesavage, C.
1969a. Modification of a Zeiss Telemeter Teletop for precision dendrometry. USDA Forest Serv. Res. Note SO-95, 7 p. South. Forest Exp. Stn., New Orleans, La.

Mesavage, C.
1969b. New Barr and Stroud dendrometer Model FP 15. J. For. 67: 40-41.

SOUTHERN FOREST EXPERIMENT STATION

1971

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SO-135

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T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

JAN 5 1972

LOSS OF ENDRIN FROM REPELLENT-COATED PINE SEED

W. F. Mann, Jr., T. E., Campbell, and J. P. Barnett

SOUTHERN FOREST EXPERIMENT STATION

Weathering causes rapid loss of endrin from the repellent coating. Direct seeding should therefore be scheduled so as to minimize the time between sowing and germination.

Direct-seeding operations are sometimes scheduled long before temperatures and soil moisture are suitable for prompt germination. A major reason for early sowing of loblolly *(Pinus taeda* L.) and slash *(P. elliottii* Engelm. var. *elliottii)* pines is to condition the seed by prolonged exposure on the ground instead of by cold stratification. A recent study in central Louisiana shows that this practice is risky because excessive endrin is lost from the protective coating by weathering when seeds are exposed up to 45 days.

THE STUDY

Single lots of loblolly and slash pine seeds, each at a moisture content of about 10 percent, were divided into two parts. One sublot of each species was soaked in water for 24 hours to approximate the moisture content obtained by cold stratification; the other was untreated. All four sublots were coated with the standard repellent formulation of Arasan 42-S [1], Endrin 50-W, aluminum powder, and a latex sticker. Adhesion was checked by subjecting seed samples to running water from a faucet for 2 minutes. All coatings were satisfactory except that of the slash seed soaked in water before treatment. Too much repellent had been applied to this sublot, and it tended to flake off in the stream of water.

Seeds were surface-sown on March 24, 1970, in a sandflat kept outdoors. The flat was 8 inches deep, and had no bottom. The coarse sand dried rapidly after a rain, thus inhibiting germination. Seeds were not watered artificially.

Two 200-seed samples were drawn at random from each sublot after 0, 15, 30, and 45 days of exposure. Extractions were then made for endrin content determinations by an infrared gas analyzer.[2]

[1] Mention of trade names is solely for information. No endorsement by the U. S. Department of Agriculture is implied.

[2] Analyses were by Dr. E. A. Epps, State Chemist, Louisiana State University, Baton Rouge, Louisiana.

RESULTS

Before exposure, the amount of endrin per 200-seed sample was about 10.5 milligrams for loblolly and 17 to 24 milligrams for slash pine (table 1).

After the first 15 days, more than 80 percent remained on three sublots, but the soaked slash pine seed that had been coated too heavily had only 58 percent. Small initial losses were probably due to low rainfall, which totaled 0.16 inch.

After 30 days, the three lots treated correctly still had 60 to 70 percent of their endrin. Overall, they lost slightly more in the second 15 days than in the first. Rainfall in this period was near normal, totaling 2.33 inches. The slash pine seed soaked in water lost less than in the first period, but was now down to 41 percent of the original amount.

Between 30 and 45 days of exposure, above-average rainfall of 3.36 inches caused heavy losses among all four lots. Only 22 to 39 percent of the endrin was left at the end of this term, regardless of how much was originally applied. Actual weights of endrin ranged from 3 to 6 milligrams for each 200-seed sample—probably too little to protect the seeds from mammals.

DISCUSSION

Patterns of endrin loss from repellent-coated seed will probably vary with rainfall. In this study early losses were low because precipitation was light, but it is logical to believe they would have been higher in a wetter period. The pertinent point, however, is that the heavy loss after 30 days indicates the inadvisability of sowing too far in advance of the time germination normally occurs.

Improvements in the sticker might reduce weathering of the repellent coating, but would require detailed research. Repellents must not be bound to the seed too firmly, because the effectiveness of endrin against certain predators is dependent on a small quantity coming loose when a seed is touched or picked up. If an improved sticker can be developed, it would probably allow a reduction in the amount of endrin currently recommended.

Table 1.—*Endrin remaining on 200 repellent-coated seeds after different periods of exposure*

Days of exposure	Loblolly				Slash			
	Dry		Soaked		Dry		Soaked	
	Mg.	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*
0	10.5	..	10.3	..	17.1	..	23.6	..
15	8.8	83.8	9.3	90.3	13.8	80.7	13.7	58.1
30	7.0	67.7	7.2	69.9	10.2	59.7	9.6	40.7
45	3.0	28.6	4.0	38.8	3.8	22.2	6.1	25.8

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CHEMICAL CONTENTS OF SOUTHERN HARDWOOD FRUITS AND SEEDS

F. T. Bonner [1]
SOUTHERN FOREST EXPERIMENT STATION

Fruits and seeds of 37 species were collected in central Mississippi and analyzed for crude fat, protein, total carbohydrates, phosphorus, calcium, and magnesium.

Information on chemical contents of the fruits and seeds of trees is sometimes useful in silviculture or in wildlife habitat research. Since 1969, the Forest Tree Seed Laboratory at State College, Mississippi, has accumulated such data on many southern species. The analyses cannot be regarded as comprehensive, since some were run in the course of research on seed maturation and others were made to test laboratory techniques. It is hoped, nevertheless, that the data will serve until definitive studies can be made.

MATERIALS AND METHODS

All seeds were 1969 or 1970 collections from trees in Mississippi, principally in Oktibbeha County in the east-central part of the State. Some samples were composites from several trees, and some came from only one tree.

Samples were dried for 24 to 48 hours at 70°C. in a forced-draft oven and then cooled in desiccators. Seeds with low fat content were ground in a Wiley mill to pass a 40-mesh screen. Those with high fat contents were ground through a 20-mesh screen or chopped finely by hand with a razor blade. Five to 10 g. of tissue were prepared from each sample.

Crude fat was determined gravimetrically by extraction with petroleum ether. Soluble and insoluble carbohydrate and nitrogen fractions were analyzed from samples extracted with 80-percent ethyl alcohol. Micro-Kjeldahl procedures were used to measure nitrogen contents, and carbohydrate analyses were made by the phenol-sulfuric acid method *(5)*. Soluble and insoluble fractions were combined for total carbohydrate and protein [percent N X 6.25 (1)] values reported here. The solid residues from alcohol extraction were tested for starch by IKI staining *(2)*.

Phosphorus, calcium, and magnesium were determined on acid extracts of ashed samples. Phosphorus was measured by the chlorostannous-reduced molybdophosphoric blue method *(1)*. Calcium and magnesium were evaluated on an atomic absorption spectrophotometer.

Many analyses were replicated two or three times; some were not replicated.

RESULTS AND DISCUSSION

Data for 37 species are summarized in table 1. Species with particularly high concentrations of carbohydrates

[1] Forest Tree Seed Laboratory, State College, Miss. The author acknowledges cooperation by Dr. G. L. Switzer, Mississippi State University, and by the Southern Hardwoods Laboratory, Southern Forest Experiment Station, Stoneville, Miss., in spectrophotometric analyses.

were *Juniperus virginiana,* all *Quercus* species, *Celtis laevigata,* and *Aesculus pavia.* Of this group, *Quercus* species and *Aesculus pavia* showed a positive stain for starch. All *Carya* species had similar carbohydrate contents, but *C. illinoensis* alone tested negative for starch.

Fat contents above 25 percent were found in *Carya ovata, C. illinoensis, Catalpa bignonioides, Liquidambar styraciflua, Sassafras albidum,* and *Zanthoxylum clava-herculis.* Seeds with protein levels above 25 percent were *Populus deltoides, Ulmus alata, Robinia pseudoacacia,* and *Liquidambar styraciflua.* These four species also had the highest phosphorus contents. Low phosphorus contents were recorded in *Quercus* and *Carya* species, and in *Liriodendron tulipifera* and *Cornus florida.*

The highest calcium contents were found in *Cornus florida, Liquidambar styraciflua, Acer negundo, Celtis laevigata, Fraxinus pennsylvanica, Ulmus alata, U. americana,* and *Carya illinoensis.* High magnesium

Table 1. – *Chemical contents of southern fruits and seeds*

Species[1]	Condition of seed	Crude fat	Total protein	Total carbohydrates	Starch[2]	P	Ca	Mg
		Pct.	*Pct.*	*Pct.*		*Pct.*	*Pct.*	*Pct.*
Acer negundo L., boxelder	intact	8.9	18.2	11.3	–	0.44	0.52	0.18
Aesculus pavia L., red buckeye	intact	1.9	8.2	42.9	++	.26	.04	.10
Carya illinoensis (Wangenh.) K. Koch, pecan	husked	32.8	9.3	13.3	3–	.09	.65	.08
C. laciniosa (Michx. f.) Loud., shellbark hickory	husked	8.7	1.6	13.8	3+	.05	.18	.04
C. myristicaeformis (Michx. f.) Nutt., nutmeg hickory	husked	15.2	5.8	16.1	3+	.06	.37	.05
C. ovata (Mill.) K. Koch, shagbark hickory	husked	37.4	5.9	13.0	3+	.15	.20	.08
Catalpa bignonioides Walt., southern catalpa	seed only	27.2	23.3	13.5	–	.51	.06	.16
Celtis laevigata Willd., sugarberry	intact	4.5	7.2	34.8	–	.21	.88	.69
Cercis canadensis L., eastern redbud	seed only	5.8	21.2	20.7	–	.38	.07	.19
Cornus florida L., flowering dogwood	depulped	6.2	5.0	14.7	–	.09	1.88	.05
Diospyros virginiana L., common persimmon	seed only	2.0	9.1	26.6	–	.20	.03	.10
Fraxinus americana L., white ash	intact	8.7	8.5	23.9	–	.22	.25	.13
F. pennsylvanica Marsh., green ash	intact	9.2	14.5	20.8	–	.34	.67	.08
Gleditsia triacanthos L., honeylocust	seed only	2.6	17.5	16.9	–	.31	.10	.14
Juglans nigra L., black walnut	husked	10.5	5.1	14.4	3–	.20	.07	.05
Juniperus virginiana L., eastern redcedar	intact	6.8	5.6	79.8	–	.14	.40	.12
Liquidambar styraciflua L., sweetgum	seed only	26.2	25.3	11.6	–	.69	1.51	.28
Liriodendron tulipifera L., yellow-popular	dewinged	1.9	2.9	19.3	–	.08	.38	.18
Nyssa sylvatica var. *sylvatica,* black tupelo	intact	10.4	3.5	14.5	–	.18	.06	.09
Platanus occidentalis L., American sycamore	clean seed	3.4	5.2	16.0	–	.18	.27	.14
Populus deltoides Bartr., eastern cottonwood	de-linted	11.9	32.8	14.8	–	.94	.08	.41
Prunus serotina Ehrh., black cherry	depulped	1.8	13.7	15.3	–	.14	.14	.09
Quercus alba L., white oak	acorn	2.9	4.6	46.6	++	.08	.22	.05
Q. coccinea Muenchh., scarlet oak	acorn	14.6	4.2	35.6	+	.07	.18	.07
Q. durandii Buckl., Durand oak	acorn	3.8	6.2	44.9	++	.09	.22	.08
Q. falcata var. *pagodaefolia* Ell., cherrybark oak	acorn	15.8	4.0	29.5	++	.06	.27	.06
Q. muhlenbergii Engelm., chinkapin oak	acorn	6.6	4.4	34.5	++	.08	.18	.08
Q. nigra L., water oak	acorn	20.3	3.8	25.8	++	.06	.32	.07
Q. phellos L., willow oak	acorn	19.6	5.9	31.2	+	.08	.18	.06
Q. shumardii Buckl., Shumard oak	acorn	9.8	3.8	29.3	++	.06	.27	.06
Q. stellata Wangenh., post oak	acorn	5.2	3.8	37.9	++	.08	.25	.06
Q. virginiana Mill., live oak	acorn	8.2	4.4	46.4	++	.06	.06	.07
Robinia pseudoacacia L., black locust	seed only	9.0	38.7	12.3	–	.68	.05	.16
Sassafras albidum (Nutt.) Nees, sassafras	intact	46.6	17.1	13.6	+	.23	.06	.11
Ulmus alata Michx., winged elm	intact	15.3	27.4	8.9	–	.52	.51	.20
U. americana L., American elm	intact	7.9	14.8	11.0	–	.38	.53	.20
Zanthoxylum clava-herculis L., Hercules-club	intact	33.6	10.2	4.0	–	.24	.20	.18

[1] Names conform with Little (4).

[2] Starch reactions: — = absent, + = light stain, ++ = heavy stain.

[3] Kernel tissue only.

contents were found in *Celtis laevigata, Liquidambar styraciflua, Populus deltoides, Ulmus americana,* and *U. alata.*

Since values represent samples from one or only a few trees of each species, their application to other areas must be made with caution. In comparison with the few data available, however, they appear to be reasonable. Korstian *(3)* reported for *Q. coccinea* (excluding the pericarps) 33.7 percent starch and soluble carbohydrates, 7.8 percent protein, and 30.8 percent fat. He found fat contents lower in white oaks than in red oaks, a relationship which is easily seen in table 1.

Data are on record for kernels of *Carya ovata* and *Juglans nigra* collected in Pennsylvania *(7).* Values for these species in table 1 are for whole nuts, but separate analyses were made for kernels. As table 2 shows, values for the two sources correspond closely.

The protein and fat values for *C. illinoensis* nuts agree very well with those published for cultivated pecan varieties *(6).*

Table 2. – *Fat, protein, and carbohydrate contents of* Carya ovata *and* Juglans nigra *kernels from Pennsylvaina* (7) *and Mississippi*

Species and source	Crude fat	Protein	Carbohydrates
		Percent	
Carya ovata			
Pa.	74.4	13.3	8.8
Miss.	70.6	12.4	5.3
Juglans nigra			
Pa.	60.2	29.2	6.7
Miss.	60.4	23.1	3.8

LITERATURE CITED

1. Jackson, M. L.
   1958. Soil chemical analysis. 498 p. Englewood Cliffs, N.J.: Prentice-Hall, Inc.
2. Jensen, W. A.
   1962. Botanical histochemistry: principles and practice. 408 p. San Francisco: W. H. Freeman and Co.
3. Korstian, C. F.
   1927. Factors controlling germination and early survival in oaks. Yale Univ. School Forest. Bull. 19, 115 p.
4. Little, E. L., Jr.
   1953. Checklist of native and naturalized trees of the United States (including Alaska). USDA Agric. Handb. 41, 472p.
5. Nalewaja, J. D., and Smith, L. H.
   1963. Standard procedure for the quantitative determination of individual sugars and total soluble carbohydrate materials in plant extracts. Agron. J. 55: 523-525.
6. Thor, C. J. B., and Smith, C. L.
   1935. A physiological study of seasonal changes in the composition of the pecan during fruit development. J. Agric. Res. 50: 97-121.
7. Wainio, W. W., and Forbes, E. B.
   1941. The chemical composition of forest fruits and nuts from Pennsylvania. J. Agric. Res. 62: 627-635.

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SITE INDEX TABLE FOR SHORTLEAF PINE IN THE BOSTON MOUNTAINS OF ARKANSAS

Edwin R. Ferguson and David L. Graney

SOUTHERN FOREST EXPERIMENT STATION

A field guide is presented for estimating shortleaf pine site index from aspect, slope shape, elevation, and degree of oak and hickory competition. The table predicted site index within 5 feet on 74 of 90 plots.

Land managers in the mountains of Arkansas need to evaluate the potential of sites for pine growth. Much of the forest there has been so badly abused by high-grading, indiscriminate grazing, and periodic wildfires that existing trees seldom reflect potential site quality, and many thousands of acres have been cleared of forest growth. Heretofore, selection among land management alternatives has been based on incomplete and sometimes inaccurate information concerning the most practical economic use of the land.

This note presents a table for estimating potential shortleaf pine site index in the Boston Mountains from easily ascertainable information on aspect, elevation, slope shape, and degree of oak and hickory competition. In a test of the table's accuracy, site index at 50 years was predicted within 5 feet on 74 of 90 sample plots.

METHODS

One hundred and two plots in a five county area were selected to represent the range of site conditions of shortleaf pine in the Boston Mountains. Colluvial soils (Allen and Holston series) were represented by 37 plots, residual soils of sandstone origin (Hartsells, Linker, and Mountainburg series) by 42 plots, and residual soils of shale origin (Enders series) by 23 plots.

Study plots were confined to even-aged 30-to 75-year-old stands of shortleaf pine and pine-hardwood mixtures. Each plot contained 3 to 5 or more dominant and codominant trees grouped as closely as possible to insure uniform soil condition. Pits were dug to bedrock or to a minimum depth of 50 inches, within the limits of each plot. All soil profiles were classified by soil scientists in the Soil Conservation Service. Soil samples were removed from each horizon for subsequent laboratory determinations of particle-size distribution, loss-on-ignition percent (a rough estimate of organic matter content), pH, and moisture contents at 1/3 and 15 atmospheres. Topographic features

such as aspect, slope position, slope shape, slope steepness, total length of slope, distance from top of slope, and elevation were also recorded for each plot. Tree age was determined by adding 4 to the number of annual rings at breast height.

DATA ANALYSIS

Some 28 individual and combined soil and topographic variables were screened by regression. Age of the sample trees was not included as an independent variable. Screening revealed 11 variables that were correlated with site index in similar ways in each of the three soil groupings. Differences between residual soils of sandstone and shale origin were minor, and these series were lumped together. Finally analyses were computed for residual soils, colluvial soils, and all soils.

Equations were developed from each regression analysis and the equation of best fit for each soil group was selected.[1]

On confirmatory plots deviations between measured and predicted site index were small and the all-soils equation performed almost as well as separate equation for residual soils and colluvial soils. Accordingly, the equation for all soils was selected for field application:

Shortleaf pine S.I. = 65.6 + 2.12 (aspect) + 2.42 (slope shape) — 4.09 (elevation in thousands of feet) — 0.80 (percent loss-on-ignition). $R^2 = 0.58$. Standard error of estimate Sy.x = 3.31.

FIELD APPLICATION

Definitions of the independent variables included in the equation are:

Aspect.—Degrees azimuth from true north coded for analysis. In general, N to NE exposures have the highest positive effect on site quality while S and SW exposures have negative effect. However plots with no aspect, i. e., essentially flat, have the highest site quality (all other factors being equal).

Slope shape.—The general configuration of the slope in the immediate vicinity of the plot. Either (1) *Convex,* where the general area tends to have a rounded surface sloping away from the plot proper; (2) *Linear,* neither rounded nor cup shaped; or (3) *Concave,* cup-shaped, where the general area tends to drain inward toward the plot. Site index increased as slope shape changed from convex through linear to the water receiving and retaining concave.

Elevation.—Elevation above sea level, determined from USGS maps and interpolated to the nearest 50 feet, where possible. In the analysis elevation was negatively correlated with shortleaf pine site index. That is, the higher the elevation the poorer the site was, if all other variables remained constant.

Loss-on-ignition.—This variable, which produced the highest correlation with site index, was determined by exposing soil samples from the A_1 horizon to temperatures of 650°C., and assuming that the percent loss reflected organic matter content. Such measurements are not practical in the field. Accordingly, an independent investigation was initiated to find some easily identifiable factor which was closely correlated with percent loss-on-ignition. After many trials, we found that the number of oak and hickory stems and sprout clumps within 40 feet of the plot center could be placed in frequency classes that were closely correlated with loss-on-ignition values. These frequency classes essentially reflect prior land use and presence or absence of hardwoods during the life of the stand.

Table 1 presents predicted site index for plots falling into six aspect groupings, eight elevation classes, three slope shapes, and four groupings of competing oak and hickory stems and sprout clumps. This table was constructed by semigraphical extrapolation of the regression equation.

This table was developed by holding all but a single variable constant in the equation and computing site indexes for various levels of the fluctuating variable. When this step was complete for each component of the equation, the data were plotted and values from the plottings were incorporated into the table to overcome rounding errors.

Site indexes were estimated with this table on 90 additional plots that had not been included in the analysis or involved in the development of the table. Estimates on 82 percent of these plots were within 5 feet of the

[1] Graney, D. L., and Ferguson, E. R. Site-quality relationships for shortleaf pine in the Boston Mountains of Arkansas. Forest Sci. 17: 16-22. 1971.

Table 1.—*Predicted shortleaf pine site index (height in feet at age 50) in the Boston Mountains by elevation, aspect, slope shape, and competition level*

Elevation (feet above sea level)	Slope shape	Aspect (azimuth)																			
		None—flat				0-75° 346-360°				76-105° 316-345°				106-135° 286-315°				136-165° 256-285°				166-255°			
		Competition level [1]																			
		0-29	30-59	60-89	90+	0-29	30-59	60-89	90+	0-29	30-59	60-89	90+	0-29	30-59	60-89	90+	0-29	30-59	60-89	90+	0-29	30-59	60-89	90+
700	Concave	74	71	68	65	73	70	67	64	72	69	66	63	71	68	65	62	70	67	64	61	69	66	63	60
to	Level	72	69	66	63	71	68	65	62	70	67	64	61	69	66	63	60	68	65	62	59	67	64	61	58
900	Convex	70	67	64	61	69	66	63	60	68	65	62	59	67	64	61	58	66	63	60	57	65	62	59	56
901	Concave	73	70	67	64	72	69	66	63	71	68	65	62	70	67	64	61	69	66	63	60	68	65	62	59
to	Level	71	68	65	62	70	67	64	61	69	66	63	60	68	65	62	59	67	64	61	58	66	63	60	57
1100	Convex	69	66	63	60	68	65	62	59	67	64	61	58	66	63	60	57	65	62	59	56	64	61	58	55
1101	Concave	72	69	66	63	71	68	65	62	70	67	64	61	69	66	63	60	68	65	62	59	67	64	61	58
to	Level	70	67	64	61	69	66	63	60	68	65	62	59	67	64	61	58	66	63	60	57	65	62	59	56
1300	Convex	68	65	62	59	67	64	61	58	66	63	60	57	65	62	59	56	64	61	58	55	63	60	57	54
1301	Concave	71	68	65	62	70	67	64	61	69	66	63	60	68	65	62	59	67	64	61	58	66	63	60	57
to	Level	69	66	63	60	68	65	62	59	67	64	61	58	66	63	60	57	65	62	59	56	64	61	58	55
1500	Convex	67	64	61	58	66	63	60	57	55	62	59	56	64	61	58	55	63	60	57	54	62	59	56	53
1501	Concave	70	67	64	61	69	66	63	60	68	65	62	59	67	64	61	58	66	63	60	57	65	62	59	56
to	Level	68	65	62	59	67	64	61	58	66	63	60	57	65	62	59	56	64	61	58	55	63	60	57	54
1700	Convex	66	63	60	57	65	62	59	56	64	61	58	55	63	60	57	54	62	59	56	53	61	58	55	52
1701	Concave	69	66	63	60	68	65	62	59	67	64	61	58	66	63	60	57	65	62	59	56	64	61	58	55
to	Level	67	64	61	58	66	63	60	57	65	62	59	56	64	61	58	55	63	60	57	54	62	59	56	53
1900	Convex	65	62	59	56	64	61	58	55	63	60	57	54	62	59	56	53	61	58	55	52	60	57	54	51
1901	Concave	68	65	62	59	67	64	61	58	66	63	60	57	65	62	59	56	64	61	58	55	63	60	57	54
to	Level	66	63	60	57	65	62	59	56	64	61	58	55	63	60	57	54	62	59	56	53	61	58	55	52
2100	Convex	64	61	58	55	63	60	57	54	62	59	56	53	61	58	55	52	60	57	54	51	59	56	53	50
2101	Concave	67	64	61	58	66	63	60	57	65	62	59	56	64	61	58	55	63	60	57	54	62	59	56	53
to	Level	65	62	59	56	64	61	58	55	63	60	57	54	62	59	56	53	61	58	55	52	60	57	54	51
2300	Convex	63	60	57	54	62	59	56	53	61	50	55	52	60	57	54	51	59	56	53	50	58	55	52	49

[1] Number of oak and hickory stems and sprout clumps within 40 feet of plot center.

actual site index at age 50 calculated from Coile and Schumacher's tables.[2]

In the Boston Mountain province we think the table will permit land managers to efficiently and effectively determine shortleaf pine growth potential. It should aid in selection of plantable sites and areas on which to concentrate intensive management practices.

[2] Coile, T. S., and Schumacher, F. X. Site index of young stands of loblolly and shortleaf pines in the Piedmont Plateau region. J. For. 51: 432-435. 1953.

SOUTHERN FOREST EXPERIMENT STATION

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SYSTEM FOR MEASURING AND COMPUTING EPHEMERAL RUNOFF FROM SMALL WATERSHEDS

P. D. Duffy and T. R. Dell [1]

SOUTHERN FOREST EXPERIMENT STATION

The system described records runoff data on tape at 2-minute intervals, translates from tape to data cards, and computes information about runoff by storm and by day, month, and year. Hydrographs can be readily constructed from the summaries provided. Equipment includes H-flumes, analog-to-digital recorders (ADR), and ADR tape translator, and a digital computer.

Small watersheds are practical for research on the effects of vegetation changes upon catchment hydrology, but accurate estimates of hydrologic change require a large number of precise measurements taken for a long period before and after treatment. For this purpose, automatic data collecting and processing are highly desirable. This paper describes a system that has collected and processed runoff data from five small research catchments in northern Mississippi for 7 years. The system of course is best suited for the 4- to 7-acre upper Coastal Plain catchments for which it was designed, but it should be applicable or adaptable to many other situations. This note and the references cited in it should provide sufficient instructions to install and use the system.

Runoff is measured in 3-foot H-flumes with a discharge capacity of 30 cubic feet per second (c.f.s.) *(5, 6,* p. 22-34). Water stage in each flume is tallied with a Fischer-Porter analog-to-digital recorder (ADR),[2] the operation of which has been described *(2, 4)*. The ADR was chosen because its output can be readily transferred to cards for computer processing. It punches stage height, or head, in binary code on a continuous roll of paper tape.

[1] Duffy is Associate Soil Scientist at Forest Hydrology Laboratory, maintained by the Southern Forest Experiment Station, USDA Forest Service, at Oxford, Miss., in cooperation with the University of Mississippi; Dell is Mathematical Statistician at Southern Forest Experiment Station in New Orleans.

[2] Mention of a trade name or manufacturer is solely to identify equipment used and does not constitute endorsement by the U. S. Department of Agriculture.

The ADR is designed to record at 5-, 15-, or 60-minute intervals. However, since the small watersheds respond rapidly and have runoff of short duration, a shorter readout was considered essential for accurate estimates of instantaneous peak discharge, time to peak rise, and volume of runoff in individual storms. A 2-minute readout was selected as a compromise between cost and accuracy.

Installation of a reliable 2-minute timing motor by the manufacturer when the study began necessitated the running of 110-volt AC power to the recorders in place of the batteries required by a standard ADR. The 110-volt line also provided power for heating tapes around stilling wells and flumes in freezing weather. Recently, however, reliable battery-powered 2-minute electronic timers have become available.

Deposited sediment samples are collected on a concrete approach section to each flume and suspended samples are collected with Coshocton samplers below each flume by standard procedures *(3)*.

TAPE INSPECTION AND TRANSLATION

Tapes are visually scanned after removal from the recorders with a simple device described by Curtis *(1)*. Lack of a water-stage trace on the tapes makes visual inspection difficult, but periods of runoff and sudden shifts in runoff can be detected. Portions of the tape for periods immediately before, during, and after runoff are retained; the rest is discarded. The retained portion is marked with date and time runoff began and stopped and is checked for obvious inconsistencies, which are noted on a translater-operator instruction sheet prepared for each tape segment. Tapes are ready for translation after inspection but are kept until there is a large enough batch to make translation and computation worthwhile. Normally this work has been done at 6-month or yearly intervals in this study.

Translation involves conversion of binary data punched on the tapes to water stage at each readout. We translate tapes on a Fischer-Porter Translator at the USDA Forest Service Coweeta Hydrologic Laboratory. Translated water stage is punched directly on cards with watershed identification, date, and card number. Since 10 stages are punched per card, each card represents 20 minutes of runoff. Card number is used to calculate time in later computations. Details of tape inspection and translation are described by Cunningham in an unpublished booklet.[3]

These translated data should be edited before runoff computations begin. Since a printout is easier to read than ADR tapes, all data can be listed and visually checked for erratic readings. A convenient alternative is a recently developed computer editing program that lists only (1) cards at the start and end of each runoff segment, (2) cards out of sequence, and (3) cards with large stage changes between consecutive readings. This list is checked for inclusion of all recorded runoff segments and to determine if large stage changes are erroneous. New cards are prepared from the corrected list if needed.

COMPUTATIONS

The program for runoff computations requires three types of input: (1) flume rating table; (2) set data, a summary of runoff that occurred prior to observations to be processed; and (3) batch data, the observations to be processed. Flume rating table is the first input for the program and needs to be read just once.

Set data, the second input, summarize duration and volume of runoff for that part of a day, month, year, or runoff event in progress at the time the current batch data begin. Set data are used to complete daily, monthly, and yearly summaries. If batch data being processed start at midday, the set data summarize runoff observed earlier that day, month, and year. Occasionally, tapes are removed from the ADR in a period of flow. In that case, the set data also describe what was taking place during the runoff event when the tape was removed. Normally, data are processed for more than one catchment in one computer run. Set data are read in immediately before the batch data for that catchment, thereby separating batch data for one catchment from those of another.

[3] Cunningham, G. B. Instructions for editing analog-to-digital recorder tapes and streamflow compilations. (Unpublished) USDA Forest Serv. Southeast. Forest Exp. Stn., Coweeta Hydrol. Lab., Franklin, N. C., 19 p. 1966.

Batch data, the water stages at 2-minute intervals, are read in, and discharge volume is computed in cubic feet and area inches for each interval. Water stage at the beginning and end of the interval is converted to discharge rate, averaged, and multiplied by time and divided by catchment area. Time when a given stage occurred is determined from the data card and the observation number on the card since cards with a given number represent the same 20-minute segment in each day. Computed discharge is accumulated by 2-minute intervals and then printed with date and time for the end of an interval which precedes an interval with a change in stage. Cumulative runoff up to that time in the event is also printed with each interval summary. Hydrographs can be readily constructed from this printed output.

Storm discharge is printed concurrently with total accumulated discharge. A storm as used in this program is not necessarily a single precipitation event but rather the period in which water stage in the flume exceeds 0.07 foot. Separation of runoff at this stage height serves two purposes. First, Coshocton sediment samplers at each flume sample only when stage is at or above 0.07 foot so only volumes of runoff at or above this stage are used to determine total suspended sediment produced. Second, in particularly wet periods runoff may continue at low rates for long periods and cannot be attributed to any particular precipitation event. The 0.07-foot stage serves as a breaking point to separate runoff attributed to a particular precipitation event from low unassignable runoff.

Computations are interrupted and summaries printed when the stage drops below 0.07 foot and at the end of each day, month, and year. The storm summary includes rate and time of peak discharge, and accumulated discharge in cubic feet and area inches when the stage exceeded 0.07 foot. Day and month summaries include duration and volume of all discharge above the 0.00-foot stage. Summaries for a year include duration and amount of discharge when stage exceeds 0.07 foot, number of events in which that stage was exceeded, and runoff duration and volume in longest storm. A batch summary is printed when all batch data for a catchment have been processed. It includes the same outputs as other summaries but only for the period for which data have been processed. Data in the batch summary are used to prepare set data for future computations.

DISCUSSION

On the watersheds we are studying, reduction of the readout interval from 5 to 2 minutes considerably increased the precision of results. In one storm with an extremely rapid rise to peak, a 5-minute readout could have truncated the maximum stage in the hydrograph by 0.10 foot and produced an instantaneous peak discharge of 5.33 c.f.s. which is 14 percent less than the actually observed 6.20 c.f.s. Total volume of flow would have been underestimated by only a little more than 1 percent. Time to peak—even to an incorrectly measured low peak—would have been at least 4 minutes longer than actually observed. Numerous cases were found where observed peak discharge rates could have been truncated by 7 percent or more with a resulting reduction in discharge per storm and change in time to reach peak. Since 2-minute readouts include less unaccounted-for variation, they should permit a calibration with individual runoff events *(7)* in less time or with a capacity to detect smaller hydrologic changes than longer readout intervals. We think these advantages offset any additional costs, particularly since reliable battery-powered timers are now available.

The summary program is designed for ephemeral runoff and studying hydrographs of individual storms, but it should be readily adaptable to other situations. For example, data selected at 2-minute intervals from continuous stage recording charts could be processed if punched on cards in the program's format. Rating tables for larger or smaller flumes or weirs could also be used with the program as written. The basic program with substantial rewriting could be used for other than 2-minute readouts of water stage. Also, with some reprogramming, the separation of flow at the 0.07-foot could be made at another arbitrarily selected stage and used, for example, to separate runoff in individual events from base flow in catchments with continuous flow.

The computer programs for editing and summarizing are written in FORTRAN and should be operable on most computers suited for scientific applications. Copies of the program decks and test examples can be obtained from the authors.

LITERATURE CITED

1. Curtis, W. R.
   1962. Tool for editing analog-to-digital tapes. J. Soil and Water Conserv. 17: 254.
2. Hibbert, A. R., and Cunningham, G. B.
   1967. Streamflow data processing opportunities and application. *In* Int. Symp. on Forest Hydrol. Proc. 1965: 725-736. N. Y.: Pergamon Press.
3. Parsons, D. A.
   1955. Coshocton-type runoff samplers. USDA Agric. Res. Serv. ARS-41-2, 16 p.
4. Pierce, R. S.
   1962. New methods for measuring streamflow. *In* Watershed Manage. Res. Conf. Proc. on Collect. and Compil. of Streamflow Rec., p. 28-31. USDA Forest Serv. Northeast. Forest Exp. Stn., Upper Darby, Pa.
5. Reinhart, K. G., and Pierce, R. S.
   1964. Stream-gaging stations for research on small watersheds. USDA Agric. Handb. 268, 37 p.
6. USDA Agricultural Research Service.
   1962. Field manual for research in agricultural hydrology. USDA Agric. Handb. 224, 215 p.
7. Ursic, S. J., and Popham, T. W.
   1967. Using runoff events to calibrate small forested catchments. *In* 14th Congr. Proc., Int. Union For. Res. Organ. Vol. 1: 319-324.

SOUTHERN FOREST EXPERIMENT STATION

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PRECOMMERCIAL THINNING OF DIRECT-SEEDED LOBLOLLY PINE

R. E. Lohrey [1]

SOUTHERN FOREST EXPERIMENT STATION

Mean diameters at age 11 years were inversely related to stand density, and growth of even the largest dominants had been influenced by thinnings at age 3. Response to thinning was most pronounced at densities of less than 1,500 stems per acre. Strip thinnings, similar to those made by machine, were as effective as selective thinnings.

When both germination and early survival are high, direct-seeded pine stands may contain 5,000 or more seedlings per acre. Some forest landowners wonder if diameter and merchantable volume growth can be increased and initial harvests expedited by thinning while trees are small and easy to eliminate. This note reports early results of a study comparing various methods and intensities of precommercial thinning in a dense loblolly pine *(Pinus taeda* L.) stand that was established in central Louisiana by direct seeding.

METHODS

The nine treatments in the study include four intensities of selective thinning, three strip thinnings, a combination of strip and selective thinning, and an unthinned check. The tallest, well-spaced trees were favored in selective thinnings, where residual density ranged from 750 to 4,350 trees per acre. The first strip thinning removed all trees on 6.6-foot-wide strips, leaving unthinned swaths of equal width. The second strip thinning, called checkerboard, consisted of two 6.6-foot strip thinnings made at right angles to each other. The third strip thinning removed trees on 7.5-foot-wide strips and left unthinned swaths 3.5 feet wide. Though the unwanted trees were uprooted by hand, the three strip treatments simulated thinnings that could be made with machines. In the combined treatment, a 6.6-foot strip thinning at age 3 years was followed by selective thinning to 1,450 trees per acre at age 5. All other thinnings were made at age 3. Treatments were installed on 0.1-acre plots and replicated three times in a randomized block design.

The study is on typical cutover longleaf pine land. After the old-growth pines were cut bluestem grasses and other native herbaceous plants covered the area. On most plots the soil is a Bowie fine sandy loam; on others it is a

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Caddo or Beauregard silt loam. Topography is nearly level, but the site is well drained except for a few small wet flats interspersed among the plots. Small mounds of sandy loam surface soil are scattered irregularly throughout the tract.

The seedbed was prepared in the fall of 1957 with an offset disk. In the following February, loblolly pine seed was broadcast by airplane at the rate of 1 pound per acre. Initial establishment and survival were good, and stand density averaged 5,740 seedlings per acre before thinning.

Plots were inventoried after the thinning at age 3 and reinventoried at age 11 years. At each inventory, all trees were counted and total height was measured on sample trees. Diameter at breast height was measured on all trees at age 11 years. As most of the trees were below merchantable size, volumes were not computed.

RESULTS AND DISCUSSION

Stand densities at age 11 years were similar to those immediately after thinning, except where residual stocking exceeded 4,000 trees per acre (table 1). In these treatments intense competition caused mortality from suppression. Most of the mortality on other plots was due to fusiform rust *(Cronartium fusiforme* Hedgc. & Hunt ex Cumm.). Additional losses from competition are expected in all treatments as the trees grow.

Table 1.—*Stocking per acre by treatment*

Treatment	Trees	
	After thinning	Age 11
	– – *No.* – –	
Unthinned check	5,033	4,443
4,350 selective	4,350	3,687
2,900 selective	2,900	2,807
1,450 selective	1,450	1,420
750 selective	750	733
6.6-foot strip [1]	2,827	2,830
Checkerboard [2]	1,500	1,590
7.5-foot strip [3]	1,573	1,463
Strip + selective [4]	1,450	1,450

[1] Trees removed from strips 6.6 feet wide, leaving unthinned swaths of equal width.
[2] Two 6.6-foot strip thinnings at right angles to each other.
[3] Trees removed from strips 7.5 feet wide, leaving unthinned swaths 3.5 feet wide.
[4] A 6.6-foot strip thinning at age 3 years followed at age 5 years by selective thinning to 1,450 trees per acre.

Mean total height of dominant and codominant trees averaged 21 feet at age 11 years. Differences between treatment means were not significant. Average heights on individual plots ranged from 14 to 26 feet and were closely related to soil conditions. The shortest trees were on small wet flats with poor surface drainage. Tallest trees were on sandy loams with good surface and internal drainage. Early height growth on all plots was slowed by the Nantucket pine tip moth *(Rhyacionia frustrana* Comst.), but most trees have outgrown injuries caused by this insect.

Mean diameter (diameter of the tree of mean basal area on each plot) of all trees ranged from 1.6 to 4.5 inches, while mean diameter of dominants and codominants ranged from 2.9 to 5.2 inches. Diameters were inversely related to numbers of trees per acre after thinning (T) and directly related to mean total height of dominant and codominant trees (H). In other words, largest average diameters were found on plots with low stand densities and tall trees. Equations were computed to determine expected mean diameters from these

Figure 1.—*Thinning this direct-seeded loblolly pine stand to 750 trees per acre at age 3 years stimulated diameter growth.*

Figure 2.—*This stand was left unthinned; it contained about 5,000 trees per acre. By age 11 years the trees were badly overcrowded and had grown slowly.*

variables. Height of dominants and codominants was used as an independent variable in lieu of site index, because applicable site curves were unavailable. Equations to determine mean diameters were:

D.b.h. (dominants and codominants)	$= 0.7063 + 0.1280(H) + 946.34(1/T)$ $R^2 = .80$ $Sy \cdot x = .28$	(1)
D.b.h. (100 largest trees per acre	$= 0.6809 + 0.1629\ (H) + 1{,}034.99\ (1/T)$ $R^2 = .85$ $Sy \cdot x = .29$	(2)
D.b.h. (250 largest trees per acre	$= 0.5393 + 0.1545(H) + 825.08(1/T)$ $R^2 = .86$ $Sy \cdot x = .25$	(3)
D.b.h. (all trees)	$= -0.6671 + 0.1183(H) + 1{,}444.63(1/T)$ $R^2 = .91$ $Sy \cdot x = .21$	(4)

All these equations were statistically significant at the 0.01 level and accounted for 80 to 91 percent of the variation in mean diameters. Values calculated from equations 1, 2, and 3 were within 0.5 inch of the actual mean on all except two plots, and diameters calculated from equation 4 were within 0.5 inch on all except one plot. Values from these equations are given in table 2 and illustrate some principles that should be widely applicable.

First, diameter response to precommercial thinning was pronounced at low densities and relatively small at residual densities above 1,500 trees per acre. Therefore, thinnings made to stimulate diameter growth should leave fewer than 1,500 trees per acre. Thinnings that leave higher densities will not increase mean diameters very much. Similar results have been reported for slash pine.[2]

Second, early precommercial thinning increased the mean diameters of dominant and codominant trees and of the 100 largest trees per acre. A dominant crown position was no assurance that a tree had been growing at its maximum rate. Even the largest dominants were stimulated by the thinning.

Third, height had a strong influence on expected mean diameters. A difference of 4 feet in mean total height accounted for 0.4 to 0.7 inch in mean diameter.

Low densities that stimulated diameter growth increased the number of trees in the larger diameter classes (table 3). On plots thinned selectively to 750 trees per acre, for example, trees 5 inches in diameter or larger were more numerous than in any other treatment. In contrast, the unthinned check excelled all other treatments in trees 3 inches and larger.

Some of the differences in diameter distributions can be attributed to variation in mean total height, which ranged from 18.1 feet in the 7.5-foot strip to 23.3 feet in the 1,450-tree selective treatments. If the trees had been of identical heights, diameter distributions would have been similar in treatments with the same density.

The effects of stand density and height were so strong as to obscure any possible influence of thinning method. To test whether such an influence existed, a variance analysis was made of the differences between observed diameters and those calculated from the equations. The differences did not vary significantly, and it was concluded that thinning method had not influenced mean diameter.

[2] Collins, A. B., III. Density and height growth in natural slash pine. USDA Forest Serv. Res. Pap. SE-27, 8 p. Southeast. Forest Exp. Stn., Asheville, N. C. 1967.

Table 2.—*Expected mean diameters at age 11 years by stand density and height*

Height of dominants and codominants (feet)	Trees per acre, age 3 years						
	750	1,000	1,500	2,000	3,000	4,000	5,000
	Inches						
	DOMINANT AND CODOMINANT TREES						
26	5.3	5.0	4.7	4.5	4.4	4.3	4.2
22	4.8	4.5	4.2	4.0	3.8	3.8	3.7
18	4.3	4.0	3.6	3.5	3.3	3.2	3.2
	100 LARGEST TREES PER ACRE						
26	6.3	6.0	5.6	5.4	5.3	5.2	5.1
22	5.6	5.3	5.0	4.8	4.6	4.5	4.5
18	5.0	4.6	4.3	4.1	4.0	3.9	3.8
	250 LARGEST TREES PER ACRE						
26	5.7	5.4	5.1	5.0	4.8	4.8	4.7
22	5.0	4.8	4.5	4.4	4.2	4.2	4.1
18	4.4	4.1	3.9	3.7	3.6	3.5	3.5
	ALL TREES						
26	4.3	3.8	3.4	3.1	2.9	2.8	2.7
22	3.9	3.4	2.9	2.7	2.4	2.3	2.2
18	3.4	2.9	2.4	2.2	1.9	1.8	1.8

Table 3.—*Number of trees per acre in and above each 1-inch diameter class at age 11 years*

Treatment	Diameter class—inches							
	1	2	3	4	5	6	7	8
	No.							
Unthinned check	4,443	2,619	1,129	306	43	3		
4,350 selective	3,687	1,886	616	143	23			
2,900 selective	2,807	1,874	876	246	36	3	3	
1,450 selective	1,420	1,387	980	520	153	16	3	
750 selective	733	673	536	376	203	70	17	7
6.6-foot strip	2,830	1,910	930	323	50	7		
Checkerboard	1,590	1,225	650	320	100	15		
7.5-foot strip	1,463	986	536	186	33	3		
Strip + selective	1,450	1,287	900	433	113	10		

This conclusion has important management implications. Strip thinnings can be made with high-production power equipment, and selective thinnings cannot. If the two methods continue to give similar results in future inventories, strip thinnings can be recommended as standard management practice, with large savings in cost by comparison with selective thinnings.

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BROWSE RESOURCES OF THE OUACHITA NATIONAL FOREST IN ARKANSAS

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SOUTHERN FOREST EXPERIMENT STATION

Browse yields in the Ouachita National Forest of Arkansas averaged 168 ovendry pounds per acre in the summer, but the quantity available declined by 81 percent when leaves fell. Yields did not differ significantly by forest type or disturbance class, and tree basal area was not a good predictor of yield. Scarcity of winter browse is probably one of the most important factors limiting white-tailed deer populations in the region.

In 1966 browse was surveyed on 1.3 million acres of the Ouachita National Forest in Arkansas to find out how much was available as food for white-tailed deer *(Odocoileus virginianus* Boddaert). A similar survey was made in 1964 on the Oklahoma portion of this forest *(3)*. This note reports results of the Arkansas survey.

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[2] Stationed at the George Washington National Forest, Harrisonburg, Va.; formerly at the Ouachita National Forest, Hot Springs, Ark.

METHODS

Browse was sampled in conjunction with a continuous forest inventory of timber. Sample plots were located by systematic grid at the approximate rate of one per 1,560 acres.

The timber type at each point was classified as pine when 50 percent or more of the stand was southern pine or eastern redcedar *(Juniperus virginiana* L.), as oak-pine when 50 percent or more of the stand was hardwood and 25 to 49 percent was pine or redcedar, and as oak-hickory when 50 percent or more of the stand was hardwood and less than 25 percent was pine or redcedar. A stand was classed as disturbed if harvest or improvement cutting had been done in the last 5 years.

At each location, the browse yields in the deer zone (up to 5 feet) were sampled on four circular milacre plots arranged in a diamond-shaped pattern 1 chain (66 feet) apart. The number of plants per species, the number and average length of current annual twigs, and utilization were recorded for all browse plants rooted within a plot. The total twig length of

each species was computed and converted to weight by applying the length-to-weight ratio technique of Schuster *(2)*. These ratios were determined by clipping, measuring, and weighing twigs from plants growing on the national forest. Length-to-weight ratios including the combined weights of twigs and leaves were used to calculate summer browse. Ratios of twig length to twig weight without leaves were used to estimate deciduous browse available during the winter. The same length-to-weight ratio was applied in summer and winter on evergreen plants. Plants in the deer zone were classed as highly, moderately, or least preferred by deer.

Differences in browse yields among timber types and disturbance classes were tested for statistical significance at the 95 percent level with Duncan's test for samples of unequal size *(5)*. Relationships of browse yields to tree basal area were explored by regression analyses.

RESULTS AND DISCUSSION

Summer browse yields ranged from 198 pounds per acre in the disturbed pine type to 111 pounds in the disturbed oak-hickory type (table 1), but weights did not differ significantly among timber types or disturbance classes. Total yields averaged 168 pounds per acre for the Arkansas area, as compared to 120 pounds per acre for the Oklahoma portion of the same national forest *(3)*.

In winter, browse availability ranged from 41 pounds per acre in the undisturbed pine to 20 pounds in the disturbed oak-pine and oak-hickory types. Again, differences among types and disturbance classes were not statistically significant (table 2). Due to the scarcity of evergreen species, only 19 percent of the summer browse weight was available in winter. In Oklahoma, winter weight was 15 percent of summer weight *(3)*.

Lowbush blueberry, poison-ivy, and saw greenbrier were the most abundant species in the highly preferred class (table 3). Post oak, hickory, and white oak were most plentiful in the least preferred category. Hickory, lowbush blueberry, and white oak occurred most frequently.

The best equations for predicting summer and winter browse availability from tree basal area each accounted for less than 2 percent of the variation in weights. Small hardwoods, which have a strong depressing effect on understory browse production *(1)*, were well distributed throughout the forest and variations in their density as well as wide variation in soil moisture holding capacity, slope, and aspect accounted for the lack of correlation between tree basal area and browse yield.

Forty-eight of the 68 browse species observed had been eaten to some extent. Since domestic livestock were scarce, deer probably accounted for most of this browsing. Saw greenbrier, lowbush blueberry, deerberry, blackberry, and cat greenbrier, which were all classed as highly preferred, were utilized most frequently (table 3).

Table 1.—*Tree basal area and summer browse yields on the Ouachita National Forest in Arkansas*

Forage type and condition	Tree basal area			Browse yields [1]			
	Pine	Hardwood	Total	Highly preferred	Moderately preferred	Least preferred	Total
	Sq. ft./acre			*Ovendry lb./acre*			
Pine							
Disturbed	55	28	83	54±16	66±62	78±12	198±65
Undisturbed	58	39	97	78±32	29±7	67±11	173±34
Oak-pine							
Disturbed	38	39	76	57±20	17±6	50±15	124±27
Undisturbed	40	46	86	54±13	20±6	57±13	131±19
Oak-hickory							
Disturbed	7	71	78	50±41	25±18	36±18	111±60
Undisturbed	3	75	78	61±20	31±10	48±16	140±30

[1] 95 percent confidence intervals.

Table 2.—*Winter browse yields (+ 95 percent confidence intervals) on the Ouachita National Forest in Arkansas*

Timber type and condition	Browse class			
	Highly preferred	Moderately preferred	Least preferred	Total
	Ovendry lb./acre			
Pine				
Disturbed	14±4	10±10	8±1	32±11
Undisturbed	30±18	4±1	7±1	41±18
Oak-pine				
Disturbed	13±4	2±1	5±2	20±4
Undisturbed	14±5	3±1	6±1	23±5
Oak-hickory				
Disturbed	13±12	4±3	3±2	20±13
Undisturbed	17±8	4±2	5±2	26±8

Browse provides cover for wildlife and is a fairly stable source of deer forage. Although deer eat forbs, grasses, mushrooms, and mast when these foods are available, they eat some browse during all seasons. Evergreen browse is a very important source of winter food, especially when mast is scarce.

On the Ouachita National Forest in Arkansas, browse was reasonably plentiful during the spring and summer, but because most understory browse species were deciduous the quantity available decreased by 81 percent in the winter. Thus, there were only 15 to 34 pounds of winter browse per acre in the top

Table 3.—*Density, frequency, and utilization of selected browse species on the Ouachita National Forest in Arkansas*

Species	Preference class	Density per milacre plot	Frequency of occurrence per milacre plot	Frequency of utilization per stocked plot
		No. of plants	*Percent*	
Lowbush blueberry (*Vaccinium vacillans* Torr.)	1	6.17	11.3	46.8
Poison-ivy (*Rhus radicans* L.)	1	1.91	7.5	9.1
Sparkleberry (*V. arboreum* Marsh.)	2	.71	8.6	10.0
Saw greenbrier (*Smilax bona-nox* L.)	1	.63	6.1	58.3
Deerberry (*V. stamineum* L.)	1	.39	2.4	42.5
Post oak (*Quercus stellata* Wang.)	3	.36	9.1	.3
Cat greenbrier (*S. glauca* Walt.)	1	.35	5.3	27.2
Hickory (*Carya* Nutt.)	3	.32	13.9	.8
White oak (*Q. alba* L.)	3	.28	10.4	.5
Red maple (*Acer rubrum* L.)	2	.26	4.9	2.4
Blackgum (*Nyssa sylvatica* Marsh.)	1	.25	7.9	3.2
Blackberry (*Rubus* [Tourn.] L.)	1	.25	2.9	33.6
Virginia creeper (*Parthenocissus quinquifolia* (L.) Planch.)	1	.23	1.9	7.5

two preference classes. Most of this material was composed of highly lignified woody twigs that are poorly digested by deer *(4)*. The scarcity of high quality winter browse, especially the more nutritious evergreen species, is probably one of the most important factors responsible for the low deer populations over much of the Ouachita National Forest.

LITERATURE CITED

1. Blair, R. M.
   1967. Deer forage in a loblolly pine plantation. J. Wildl. Manage. 31: 432-437.
2. Schuster, J. L.
   1965. Estimating browse from twig and stem measurements. J. Range Manage. 18: 220-222.
3. Segelquist, C. A., and Pennington, R. E.
   1968. Deer browse in the Ouachita forest in Oklahoma. J. Wildl. Manage. 32: 623-626.
4. Short, H. L., and Reagor, J. C.
   1970. Cell wall digestibility affects forage value of woody twigs. J. Wildl. Manage. 34: 964-967.
5. Steel, R. G. D., and Torrie, J. H.
   1960. Principles and procedures of statistics. 481 p. N. Y.: McGraw-Hill Book Co., Inc.

SOUTHERN FOREST EXPERIMENT STATION

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YELLOW-POPLAR, LOBLOLLY PINE, AND VIRGINIA PINE COMPARED IN CUMBERLAND PLATEAU PLANTATIONS

Glendon W. Smalley and Kenneth Pierce [1]

SOUTHERN FOREST EXPERIMENT STATION

Ten years after planting on cleared north-facing slopes, loblolly pines averaged 32.8 feet in height and 5.4 inches in diameter, Virginia pines 27.5 feet and 4.5 inches, and yellow-poplars 21.9 feet and 2.2 inches. Survival was 72 percent or greater for all species on all topographic positions except bottoms. Yellow-poplar was most sensitive to topographic position, loblolly was intermediate, and Virginia pine least sensitive.

Forest scientists at the Sewanee Silviculture Laboratory are assessing the suitability of several commercially valuable pines and hardwoods for the wide array of sites on the Cumberland Plateau and Highland Rim of middle Tennessee and northern Alabama. In this report the 10-year performance of loblolly pine *(Pinus taeda* L.), Virginia pine *(P. virginiana* Mill.), and yellow-poplar *(Liriodendron tulipifera* L.) are compared in plantations on north-facing slopes of moderate grade. These three species occur on extensive acreage and should be favored in managing existing stands and reforesting abandoned fields and cutover land in the area.

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METHODS

The plantings were on the Flat Top Experimental Forest [2] at latitude 33° 38′ N. and longitude 87° 00′ W. in Jefferson County, Alabama. Physiographically, the area is at the southern extremity of the Cumberland Plateau. The interbedded sandstone and shale give rise to moderately deep enders and shallow Townley soils on ridgetops. Soils on slopes are commonly shallow and belong to the Montevallo series. The bottom soils, derived from colluvium and alluvium of the uplands, are members of the Pope-Philo-Stendal-Atkins drainage catena. Texture of the surface soils ranges from sandy loam to silt loam. Elevation ranges from 260 to 620 feet above sea level.

The study areas, consisting of north-facing slopes, were cleared of mixed stands of pine—

[2] Formerly maintained in cooperation with U.S. Pipe and Foundry Company, Birmingham, Ala.

loblolly, shortleaf, and Virginia—and hardwood—oaks *(Quercus* spp.), hickories *(Carya* spp.), and an occasional yellow-poplar prior to planting. Merchantable trees were sold, and tops and unmerchantable trees were removed from the plots. Hardwood stumps were treated to inhibit sprouting.

Each of the three study areas (blocks) was divided into five topographic positions designated bottom, lower slope, midslope, upper slope, and ridge. The bottom positions straddled intermittent streams. Ridge positions usually had less than 10 percent slope. On positions designated as slopes, gradients ranged up to 44 percent and averaged about 39 percent. Each topographic position in each block contained three 40- by 48-foot plots. In two blocks the plots were laid out with the long side on the contour, while in the third block the short side was on the contour.

Seeds of the three study species were collected and seedlings grown in a nursery bed on the experimental forest. The 1-0 seedlings were lifted and graded as small, medium, and large just prior to outplanting in March. Fifteen medium and 15 large seedlings of individual species were planted on assigned subplots, which consisted of five rows of six seedlings. Spacing was 8 by 8 feet. Measurements were confined to the central 12 trees in the subplot.

Within blocks, species were randomly assigned to the three subplots on each topographic position. There were a total of 45 subplots. Values for survival, total height, and diameter at breast height were compared by analyses of variance including orthogonal partitions of main effects and interactions. Tests of significance were made at the 95 percent level of probability.

RESULTS

Survival

First-year survival equalled or exceeded 85 percent on all positions for all species. Yellow-poplar survived better than the pines; the pines survived about equally well. Topographic position affected only yellow-poplar mortality, which was greater in the bottoms than at higher positions.

After 5 years survival of all three species was 75 percent or greater on all ridge and slope positions. In bottoms, an average of 38 percent of the trees had died. More poplars than pines had died.

Mortality was negligible after the fifth year. At age 10 survival equalled or exceeded 72 percent for all species on ridge and slope positions (table 1). In the bottoms 69 percent of the loblolly pines, 61 percent of the Virginia pines, and 56 percent of the yellow-poplars were alive. Only the effect of topographic position was significant. This was attributed mainly to the lower survival in the bottoms as compared to the slopes and ridges.

Height

Yellow-poplar seedlings were much taller than the pines when planted and the pines did not catch up until the third year (fig. 1). At age 2 the average height of all species on all topographic positions varied by less than 1 foot. Thereafter, both pines were taller than yellow-poplar on all but lower slopes.

At age 10 loblolly was significantly taller than Virginia pine; both pines were significantly taller than yellow-poplar (table 1). The height-growth patterns of the pines were nearly linear (fig. 1).

Table 1.—*Yellow-poplar (YP), loblolly pine (LP), and Virginia pine (VP) performance, by topographic position, at plantation age 10 years*

Topographic position	Survival				Total height				Diameter breast height			
	YP	LP	VP	Mean	YP	LP	VP	Mean	YP	LP	VP	Mean
	Percent				*Feet*				*Inches*			
Ridge	88.9	75.0	72.2	78.7	14.0	30.7	25.7	23.5	1.4	5.1	4.5	3.7
Upper	86.1	80.6	86.1	84.3	17.0	31.0	27.0	25.0	1.7	5.3	4.4	3.8
Mid	94.4	80.5	86.1	87.0	20.3	31.0	26.7	26.0	2.0	4.9	4.5	3.8
Lower	86.1	75.0	86.1	82.4	30.3	32.7	29.0	30.7	3.0	5.3	4.3	4.2
Bottom	55.6	69.4	61.1	62.0	27.7	38.7	29.0	31.8	2.8	6.6	4.6	4.7
Mean	82.2	76.1	78.3		21.9	32.8	27.5		2.2	5.4	4.5	

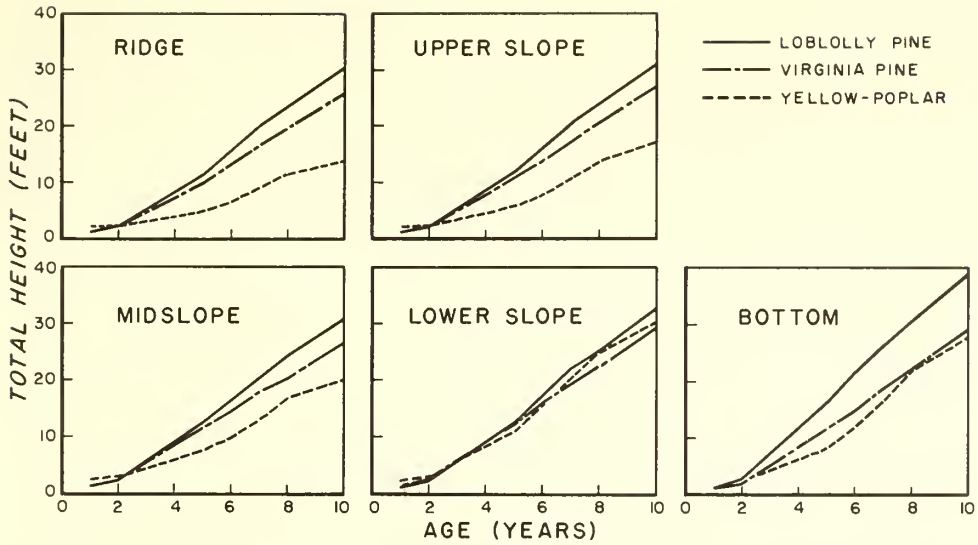

Figure 1.—*Height growth of loblolly pine, Virginia pine, and yellow-poplar, by plantation age and topographic position.*

The effect of topographic position was also significant. Tree heights in bottoms and on lower slopes did not differ significantly, but when successive lower positions were grouped and compared with the next higher position significant differences occurred.

Loblolly height varied only slightly from ridges to lower slopes. There was a sizable increase from lower slopes to bottoms. Loblolly pines in bottoms averaged 8 feet taller than those on ridges.

The response of Virginia pine to topographic position was negligible. Virginia pines in bottoms were 3.3 feet taller than those on ridges.

Yellow-poplars on lower slopes were much taller than those on higher positions and 2.6 feet taller than those in bottoms. At age 5 this difference between lower slopes and bottoms was 2.8 feet. Yellow-poplars in bottoms averaged 13.7 feet taller than those on ridges.

Because of the somewhat different response of each species to topographic position, the interaction term was significant. However, the magnitude of the differences was small in contrast to main effects. Loblolly outgrew Virginia pine on all topographic positions. Yellow-poplar was shorter than the pines on all positions except lower slopes where it slightly exceeded Virginia pine. Pines in bottoms and on lower and midslopes were significantly taller than yellow-poplars on upper slopes, and pines in bottoms and on the slopes were significantly taller than yellow-poplars on ridges.

Diameter

In average diameter, loblolly pine was significantly larger than Virginia pine; both pines were significantly larger than yellow-poplar. The diameter of loblolly pine was largest on all positions, Virginia pine was second, and yellow-poplar third.

The effect of topographic position was also significant. Trees in bottoms and on lower slopes had significantly larger diameters than those on midslopes. Trees in bottoms and on all slopes had significantly larger diameters than those on ridges.

The diameter of yellow-poplar was related to topographic position in the same manner as height. It increased downslope from ridges to lower slopes, then decreased slightly from lower slopes to bottoms.

Except for the sizable increase from lower slopes to bottoms, the effect of topographic position on the diameter of loblolly pine was nil. The diameter of Virginia pine varied by only 0.3 inch among topographic positions.

DISCUSSION

Site potential for tree growth is clearly least on ridges and progressively better downslope. The same is true for growth of invading vegetation.

The three planted tree species differ in ability to use moisture and nutrients. Yellow-poplar requires moist well-drained soil for

optimum growth. For best growth in the interior uplands, loblolly also needs moist, well-drained soil, but it grows better than yellow-poplar on drier sites. Virginia pine grows reasonably well on a variety of sites. On above-average sites it tends to be crowded out by other species. On the other hand, Virginia pine grows on sites too poor for many species to exist. It is distinctly less tolerant of wet sites and impeded drainage than loblolly *(3)*.

Most of the mortality, particularly of yellow-poplar in the bottoms, can probably be attributed to the rank growth of grass, weeds, blackberries *(Rubus* spp.), briars *(Smilax* spp.), honeysuckle *(Lonicera japonica* Thunb.), and muscadine *(Vitis rotundifolia* Michx.) which appeared during the first growing season. Some additional competition was exerted by volunteers originating from seed that sifted out of the litter during clearing or blew in from the surrounding seedwalls. A weeding consisting of lopping with brush hooks between the second and third growing seasons was unsuccessful in controlling competing vegetation.

In bottoms, the rapid height growth of loblolly enabled it to overtop the competition. Why Virginia pine did not grow taller in bottoms than it did on lower slopes is unknown. These narrow bottoms are not too wet for Virginia pine since it occurs naturally as scattered trees in hollows over much of the experimental forest. Probably competition has retarded the growth of Virginia pine to a degree. Virginia pine may be incapable of utilizing additional moisture and nutrients.

Certainly, competition is the major cause for the reduced growth of yellow-poplar in bottoms. Trees averaged 2.6 feet shorter and 0.2 inch smaller in d.b.h. than those on lower slopes after 10 years. Yellow-poplar should be growing very rapidly on these better than average sites *(2)*. The invading vegetation was more dense and vigorous than in similar bottoms of other yellow-poplar plantations on the experimental forest, and less effort was made to control it.

On slopes and ridges loblolly has an edge over Virginia pine in both height and diameter growth, and both pines are growing faster than yellow-poplar. On ridges soil depth exceeded 2 feet, which probably explains why loblolly is outgrowing Virginia pine. Where soil is shallow, Virginia pine will probably outperform loblolly.

The difference in height between trees growing on ridges and in bottoms is an expression of site sensitivity of the species (table 1). Yellow-poplar was most sensitive, loblolly was intermediate, and Virginia pine least sensitive.

All three species have been planted on a variety of forested sites throughout middle Tennessee and northern Alabama. Ten-year performance in eight other plantations is compared with that of the present study (Plantation 1) in table 2.

Yellow-poplar height in the bottoms of Plantation 1 was 2.4 feet less and diameter 0.3 inch larger than in bottoms of Plantation 2. At age 5, total height in bottoms of these two plantations differed by 10.2 feet. Evidently the effect of early competition is diminishing with time. The faster height growth of Plantation 1 from age 5 to 10 could be a response to the wider spacing caused by high mortality.

On upper and midslopes yellow-poplars in Plantation 1 were shorter than those in Plantation 2. On lower slopes poplars were 4.0 feet taller and 0.8 inch larger than those in Plantation 2. The diameter of poplars on upper slopes was slightly smaller than in Plantation 2.

Both height and diameter growth of yellow-poplar on southern Cumberland Plateau ridges of Plantation 1 were poor in comparison with growth on broad Plateau ridges near Sewanee (Plantations 4 and 5) and on narrow Highland Rim ridges (Plantation 9), but equalled growth on a narrow ridge with shallow soil near Sewanee (Plantation 6).

The height of Plantation 1 yellow-poplar on north midslopes nearly equalled that obtained on a gentle east slope near Sewanee (Plantation 7). Poplars in bottoms of Plantation 1 grew taller than those in V-bottoms and on lower slopes on the same experimental forest (Plantation 3). Yellow-poplar on a northwest-facing bench below the Cumberland escarpment near Sewanee (Plantation 8) outperformed all three plantings in Alabama bottoms (Plantations 1, 2, and 3).

Loblolly height on Plantation 1 ridges exceeded that on Plateau and Highland Rim ridges (Plantations 4, 5, 6, and 9). The aver-

Table 2.—*Performance of 10-year-old yellow-poplar, loblolly pine, and Virginia pine planted at nine locations on the Cumberland Plateau and Highland Rim*

Location, plantation number, and site description	Topographic position	Yellow-poplar		Loblolly pine		Virginia pine	
		Height	Diameter	Height	Diameter	Height	Diameter
		Feet	*Inches*	*Feet*	*Inches*	*Feet*	*Inches*
Plateau-hollow							
1—Graysville, Ala.; Enders, Montevallo, and Philo; north slope; 6 x 8 ft.	Ridge	14.0	1.4	30.7	5.1	25.7	4.5
	Upper slope	17.0	1.7	31.0	5.3	27.0	4.4
	Midslope	20.3	2.0	31.0	4.9	26.7	4.5
	Lower slope	30.3	3.0	32.7	5.3	29.0	4.3
	Bottom	27.7	2.8	38.7	6.6	29.0	4.6
2—Graysville, Ala.; Enders, Montevallo, and Philo; north slope; 5 x 6 ft.	Upper slope	21.6	1.8				
	Midslope	24.9	2.2				
	Lower slope	26.3	2.2				
	Bottom	30.1	2.5				
3—Graysville, Ala.; Enders, Montevallo, and Pope; 5 x 5 ft.	V-bottom and lower slope	18.6	1.6				
Plateau-ridge							
4—Sewanee, Tenn.; Hartsells, Linker, and Cotaco; 6 x 8 ft.	Broad ridge	16.2	1.7	27.8	4.4	24.5	3.8
5—Sewanee, Tenn.; Hartsells and Linker; 6 x 8 ft.	Broad ridge	16.6	1.9	23.7	3.9	23.1	3.9
6—Sewanee, Tenn.; Hartsells and Ramsey; 6 x 8 ft.	Narrow ridge	13.6	1.4	21.6	3.6	22.0	3.6
7—Sewanee, Tenn.; Hartsells, elevation 1,850 ft.; 5 x 5 ft.	East slope (4%)	21.4	2.1				
Plateau-bench							
8—Sewanee, Tenn.; Jefferson; elevation 1,600 ft.; 5 x 5 ft.	Bench (northwest)	35.4	3.2				
Highland Rim-ridge							
9—Centerville, Tenn.; Mountview; 6 x 8 ft.	Narrow ridge	19.2	2.0	28.2	5.2	23.1	4.0

age d.b.h. of 5.1 inches was best of all ridge plantations except number 9 on the Highland Rim.

Virginia pine height and diameter growth on Plantation 1 ridges exceeded growth on Plateau and Highland Rim ridges (Plantations 4, 5, 6, and 9) but the differences were small. There were no pine plantations on slope and bottom positions old enough for comparison.

CONCLUSIONS

Based on 10-year performance, loblolly pine is the best species to plant or to favor in existing stands on north slopes, ridges with deep soils, and well-drained bottoms on the Cumberland Plateau in northern Alabama. Virginia pine grows reasonably well on a variety of sites and may be better suited than loblolly to warm slopes and sites with shallow soil. Although its performance was not best in this particular study, there is ample evidence that yellow-poplar will perform about as well as loblolly pine on lower slopes and in bottoms. And there are advantages to breaking up large areas of nearly pure pine with stringers of high-quality hardwoods along the drainages.

Our experience indicates that yellow-poplar can be readily planted on the Cumberland Plateau and Highland Rim of Tennessee and Alabama without resorting to specialized techniques. Ordinary nursery stock will survive and grow well on a variety of sites if competition is adequately controlled *(1)*.

LITERATURE CITED

1. Russell, T. E., Loftus, N. S., Mignery, A. L., and Smalley, G. W.
   1970. Planting yellow-poplar in central Tennessee and northern Alabama. USDA Forest Serv. Res. Pap. SO-63, 17 p. South. Forest Exp. Stn., New Orleans, La.
2. Smalley, G. W.
   1969. Ten-year growth of yellow-poplar planted in north Alabama. J. For. 67: 567-568.
3. USDA Forest Service.
   1965. Silvics of forest trees of the United States. U. S. Dep. Agric., Agric. Handb. 271, 762 p.

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BROWN-SPOT RESISTANCE IN NATURAL STANDS OF LONGLEAF PINE SEEDLINGS

William D. Boyer [1]

SOUTHERN FOREST EXPERIMENT STATION

An average of 10 percent of longleaf pine (Pinus palustris *Mill.) seedlings in several natural populations remained nearly free of brown-spot needle blight* (Scirrhia acicola *(Dearn.) Siggers) year after year, despite high infection levels in the population as a whole. In one study, these individuals averaged 8 feet taller at age 24 than surviving trees that were less resistant to the disease.*

Brown-spot needle blight *(Scirrhia acicola* (Dearn.) Siggers), the most serious disease of longleaf pine *(Pinus palustris* Mill.) seedlings, delays height growth by defoliating and may eventually kill many seedlings *(4, 5)*. Some individuals seem to be genetically resistant to brown spot *(2, 5)*, and this characteristic is being exploited in the development of disease-resistant strains *(3)*. No quantitative information has been published, however, on the occurrence of brown-spot-resistant seedlings in natural populations. Four studies of natural regeneration problems provide some of the necessary information, which is reported in this paper.

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METHODS

Detailed information was gathered in four separate studies on the development of 1,783 individual longleaf pine seedlings for periods of at least 4 successive years. Three studies were done on the Coastal Plains of south Alabama on the Escambia Experimental Forest or Conecuh National Forest, and one in the Mountain Province of northern Alabama. Information on the location, year of seeding, and seedling examinations in each study are given in table 1.

Individual seedlings selected for observation were identified by a wire pin on the ground, and their locations were marked on plot maps. In brown-spot examinations, each marked longleaf pine seedling was inspected in the winter, and the proportion of current-year foliage destroyed by brown spot was estimated to the nearest 10 percent.

Table 1.—*Study locations and seedling observations*

Study	Location	Year of seeding	Number of winter examinations	Ages of examined seedlings
1	Escambia Experimental Forest Conecuh National Forest	1947	7	1-10
2 a	Escambia Experimental Forest	1957, 1958	7	1, 2-7, 8
b	Escambia Experimental Forest	1957, 1958	6	2, 3-7, 8
3	Escambia Experimental Forest	1955	4	2-5
4	Coosa County, Alabama	1961	6	1-6

Four brown-spot infection classes were set up on the basis of percent of infection: (1) light (0-10 percent), (2) moderate (20 percent), (3) heavy (30-40 percent), and (4) severe (50 percent or more). Each seedling was assigned to the class in which it fell in the year when it was most severely infected. Class rating achieved over a number of years should be a good indication of the relative susceptibility of seedlings, but that for 1 or 2 years apparently is not. For example, even in the worst single infection year the number of class 1 seedlings was more than double the number that remained in class 1 for 4 or more years.

Individual longleaf pine trees in study 1 were relocated during the late summer of 1971 to check for relationships between seedling brown-spot status and subsequent survival and growth. Heights and diameters of survivors were measured at that time, when trees were 24 years old.

RESULTS

Small but significant fractions of the natural longleaf pine seedling populations appeared to be resistant to brown spot. The proportion that had no more than 10 percent infection (class 1) for the entire period of observation was about 12 percent in south Alabama and 5 percent in the north (table 2). If seedlings no more than moderately infected (class 2) are included, the relatively resistant fraction ranged from 12 to 28 percent of the stands. In terms of trees per acre at the final examination seedlings in class 1 and 2 combined amounted to about 500 per acre in studies 1 and 3, 900 in study 2, and 2,000 in study 4. The large number in study 4 was due to a high initial stocking of seedlings.

Table 2.—*Distribution of marked longleaf pine seedlings among brown-spot infection classes based on highest infection recorded over all years of observation*

Brown-spot infection class	Study			
	1	2	3	4
	Percent			
1	12.8	12.2	12.1	4.7
2	8.3	9.8	16.2	6.9
3	19.9	33.3	33.1	24.0
4	59.0	44.7	38.6	64.4

The proportion of seedlings lightly infected by brown spot will be influenced by intensity of the disease in the area. When average infection levels are light, of course, a large percentage of the seedlings will be in class 1. When brown-spot infection levels are high for several years, most of the susceptible seedlings will become diseased. The severity of infection on an individual seedling in any given year probably reflects complex interactions between the current degree of seedling susceptibility and microenvironmental fluxes affecting the disease itself.

Average infection levels reached during the worst year in each study were 31, 32, 42, and 46 percent for studies 3, 2, 1, and 4, respectively. Among studies, an increasing severity of the disease produced a net shift of seedlings into the highest brown-spot infection class. Except in study 4, the proportion of class 1 seedlings was unaffected.

Seedlings that remained free of brown spot (class 1) were nearly always larger, as a group, than those that had moderate to severe infection at some time. For example, in study 1, average root-collar diameters of 10-year-old

seedlings in infection classes 1 through 4 were 1.49, 1.35, 1.10, and 0.95 inches, respectively. Sixty-three percent of class 1 seedlings were in active height growth (0.5 foot or more to base of bud), compared to 40 percent for class 4.

The initial size advantage of the brown-spot-resistant longleaf pines in study 1 has widened through age 24 (table 3). Class 1 trees averaged 8 feet taller than those in both classes 3 and 4. Class 2 trees were nearly as large as class 1; the height gap that separated them narrowed between ages 10 and 24. Except for survival, there was no difference in performance between classes 3 and 4.

Table 3.—*Fate of trees through age 24, by brown-spot infection class through age 10*

Brown-spot infection class	Survival age 10-24	Average size of survivors		
		Age 10	Age 24	
		Height	Height	D.b.h.
	Percent	*Feet*	*Feet*	*Inches*
1	64	4.5	37	4.0
2	64	2.6	35	3.7
3	40	2.5	29	3.1
4	20	2.1	29	3.2

Differential mortality increased the proportion of brown-spot-resistant trees in the stand, and 39 percent of all survivors to age 24 were in class 1 or 2. These two classes comprised 56 percent of the dominant trees exceeding 40 feet in height. All five of the trees over 50 feet in height were class 1 seedlings.

DISCUSSION

Apparently, a small but important fraction of longleaf pine seedlings in natural stands is able to remain substantially free of brown-spot infection year after year, even though most of their neighbors are heavily infected. Most of these seedlings have superior juvenile growth, which may reflect the lack of significant suppression by brown spot, or may be associated with some common factors behind both growth and freedom from infection.

Brown-spot-free seedlings, as a group, survived better and grew more rapidly than other seedlings through age 24. Similar observations were reported by Wakeley *(6)* for longleaf pine plantations at 30 years of age. As the stand develops, the disease-free individuals account for an increasing proportion of the dominant stand.

The development of resistant strains of longleaf pine with desirable growth properties is a long-term undertaking. In the meantime, the manager can capitalize upon the reservoir of disease resistance that may exist in his longleaf pine forests. This potential should be recognized and fully exploited through cultural and cutting practices designed to favor these superior trees, beginning with the earliest years of the stand. In the past, prescribed burning for control of brown spot in grass-stage seedling stands has often discriminated against the disease-free seedlings because it kills the ones that are in the early stages of height growth. Croker *(1)* pointed out the importance of basing fire prescriptions on the condition of these superior "crop seedlings" rather than the seedling population as a whole.

Natural regeneration following a good longleaf pine seed crop often provides established seedlings in such numbers that the superior fraction alone can provide a full stand. The manager has an opportunity to improve the quality of his longleaf stands by reserving trees that are not only disease resistant, with desirable growth characteristics, but also demonstrably and perhaps uniquely adapted to local site conditions.

LITERATURE CITED

1. Croker, T. C., Jr.
   1967. Crop-seedling method for planning brown-spot burns in longleaf pine. J. For. 65: 488.

2. Derr, H. J.
   1963. Brown-spot resistance among F_1 progeny of a single, resistant longleaf parent. *In* Forest Genet. Workshop Proc. 1962: 16-17. South. Forest Tree Improv. Comm. and Soc. Am. For. Tree Improv. Comm.

3. Derr, H. J., and Melder, T. W.
   1970. Brown-spot resistance in longleaf pine. Forest Sci. 16: 204-209.

4. Lightle, P. C.
1969. Brown-spot needle blight of longleaf pine. USDA Forest Serv. Forest Pest Leafl. 44 (rev.), 7 p.

5. Siggers, P. V.
1944. The brown spot needle blight of pine seedlings. U. S. Dep. Agric. Tech. Bull. 870, 36 p.

6. Wakeley, P. C.
1970. Thirty-year effects of uncontrolled brown spot on planted longleaf pine. Forest Sci. 16: 197-202.

SOUTHERN FOREST EXPERIMENT STATION

1972

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NITROGEN FERTILIZATION INCREASES COTTONWOOD GROWTH ON OLD-FIELD SOIL

B. G. Blackmon and E. H. White [2]

SOUTHERN FOREST EXPERIMENT STATION

Nitrogen (150 lb./acre as NH_4NO_3) applied to a 6-year-old eastern cottonwood plantation in an old field on Commerce silt loam soil increased diameter, basal area, and volume growth by 200 percent over untreated controls. The plantation did not respond to 100 pounds P per acre from concentrated superphosphate.

Eastern cottonwood grows very rapidly when planted on fertile alluvial soils of the Mississippi River Floodplain and given proper care *(9)*. However, with increased flood control and exhaustive agriculture, mainly cotton farming, the fertility of many sites has declined to the point where fertilization, particularly with nitrogen, is necessary for the production of agronomic crops. Although field fertilizer trials have not previously been conducted in cottonwood plantations on old fields in the Mississippi River Floodplain, it is well known that the species is sensitive to soil fertility *(1, 2, 3, 4, 5, 10, 14)*. This paper reports the first-year results of nitrogen and phosphorus fertilization of a young cottonwood plantation on a site that had been cropped for many years.

[1] Cooperative study with Crown Zellerbach Corp., Bogalusa, La.

[2] The senior author is Soil Scientist at the South. Hardwoods Lab., which is maintained at Stoneville, Miss., by the South. Forest Exp. Stn., in cooperation with the Miss. Agric. For. Exp. Stn. and the South. Hardwood Forest Res. Group. When this work was completed, the junior author was also Soil Scientist at the South. Hardwoods Lab.; he is now Assist. Prof. of Forestry, Univ. of Ky., Lexington, Ky.

METHODS

Site and stand condition.—The study site is in western Mississippi in the floodplain of the Mississippi River. The soil is a Commerce silt loam, overlaid by a thin layer ($<$ 6 inches) of clay.

Commerce soils are members of the fine-silty, mixed, nonacid, thermic family of Aeric Fluventic Haplaquepts. They are somewhat poorly drained and have developed in alluvial deposits from the Mississippi River. Slopes range from 0 to 5 percent. Analysis of soils from the study area indicated a high phosphorus level (130 p.p.m. with Bray No. 2 extractant) and a very low level of total nitrogen (0.038 percent or 760 pounds per acre). Understory vegetation on the test site was predominantly Johnson grass *(Sorghum halepense*

[L.] Pers.), typical of most old fields in the area. Average rainfall is 50 to 60 inches annually.

When treated, the study plantation was 6 years old and contained approximately 32 square feet per acre basal area and 590 cubic feet per acre total volume. Tree diameters averaged 3.7 inches, and mean height was 39 feet. On Commerce soils recently cleared of natural timber, planted cottonwood can be expected to attain heights of 50 to 60 feet in 6 years. Krinard *(7)* reported heights up to 67 feet in 6 years on Commerce soil.

When fertilizers were applied, the trees had classic symptoms of nitrogen deficiency—very sparse crowns, small yellowish-green leaves, and generally poor vigor. Understory vegetation was sparse and also appeared nutrient-deficient.

Treatment and experimental design.—The study design was a randomized block with three replications of four treatments: (1) control (no fertilizer), (2) 100 pounds of P per acre, (3) 150 pounds of N per acre, and (4) 150 pounds of N plus 100 pounds of P per acre. Fertilizer source materials were ammonium nitrate (33 percent N) and granular concentrated superphosphate (20 percent P). Fertilizers were broadcast on May 8, 1970, by hand and incorporated by light disking over a 0.17-acre plot containing approximately 100 trees spaced 8 by 10 feet. Control plots were also disked at the time of treatment. The center six rows by four rows were used for measurement. Growth response to treatment was assessed in terms of height, diameter, basal area, and total volume.

An identical study was installed in an adjacent area from which 50 percent of the stems (every other diagonal row) had been removed before fertilization.

Foliage analyses.—Foliage samples were collected from upper and lower crowns of trees on each plot in mid-August 1970. Each sample was a composite of 60 fully developed leaves, 20 leaves from each of three dominant trees per measurement plot. Samples were dried at 65°C., weighed, and ground to pass through a 40-mesh screen. Subsamples of ground foliage were analyzed for total N by a macro-Kjeldahl procedure. Other subsamples were dry-ashed for 5 hours at 550°C., the ash dissolved in dilute HCl, and solutions analyzed for total P by the molybdophosphoric blue method.

RESULTS

Four weeks after treatment, all trees on N and NP plots had larger, darker green leaves and fuller crowns than trees on check and P-treated plots. This visible response was confirmed by mensurational and foliage composition data collected at the end of the first season after treatment.

Growth.—Four months after fertilization, average stem d.b.h. had increased by 0.63 inch on plots treated with nitrogen and only 0.21 inch on check plots (table 1). A combination of N and P resulted in slightly less diameter growth than N alone. Growth on plots treated

Table 1.—*Influence of fertilizer on growth of a 6-year-old cottonwood plantation*

Fertilizer [1]	Growth (1970) [2]			
	Diameter	Basal area	Height (5 largest trees)	Volume
	– – Inch – –	*Sq. ft./acre*	*– – Ft. – –*	*Cu.ft./acre*
O	0.21 a [3] (—)[4]	3.99 a (—)	4.1 a (—)	76.2 a (—)
P	.23 a (10)	4.39 a (10)	4.4 a (7)	79.3 a (4)
N	.63 b (200)	11.77 b (195)	8.4 b (105)	231.7 b (204)
N-P	.57 b (171)	11.13 b (179)	7.7 b (88)	211.4 b (178)

[1] O = check, no fertilizer; P = 100 pounds P per acre from concentrated superphosphate; N = 150 pounds N per acre from ammonium nitrate; N-P = combination of the above.

[2] Mean based on approximately 60 trees except for height.

[3] Means followed by the same letter (vertically) are not significantly different at the 0.05 level.

[4] Numbers in parentheses indicate percentage increase over control.

with phosphorus alone was not different from that on the control plots.

Basal area growth (table 1) followed a pattern similar to that of diameter growth. Controls increased in basal area by about 4 square feet per acre while nitrogen alone produced almost 12 square feet. Phosphorus alone had very little effect, while N plus P resulted in slightly less basal area growth than N alone.

Average height (table 1) of the five largest trees per plot ranged from 35 to 47 feet. Mean height increases for the one season were approximately 4 feet for check plots, compared to about 8 feet for N- and NP-treated plots.

Likewise, the greatest volume response (table 1) resulted from the application of 150 pounds of N per acre. Statistical tests revealed that the N and NP treatments did not produce significantly different results; both were superior to the control and P treatment. Nitrogen alone produced 156 cubic feet per acre, three times as much stemwood volume as the control. Phosphorus in combination with N was slightly but not significantly less effective than N alone.

In the plantation from which 50 percent of the stems had been removed, the pattern of growth response was very similar to that of the unthinned stand.

Foliar N and P concentrations.—Foliage levels of nitrogen (table 2) were increased by nitrogen fertilization from about 1.6 to 2.3 percent in the upper crown and from about 1.3 to 1.7 percent in the lower crown.

Table 2.—*Effect of fertilizer on foliar N and P levels in 6-year-old cottonwood trees*

Fertilizer [1]	Concentration			
	Upper crown		Lower crown	
	N	P	N	P
	Percent			
O	1.61 a [2]	0.18 a	1.32 a	0.18 a
P	1.57 a	.16 a	1.25 a	.19 a
N	2.24 b	.17 a	1.74 b	.15 b
N-P	2.39 b	.18 a	1.75 b	.17 b

[1] O = check, no fertilizer; P = 100 pounds P per acre from concentrated superphosphate; N = 150 pounds N per acre from ammonium nitrate; N-P = combination of the above.

[2] Means followed by the same letter (vertically) are not significantly different at the 0.05 level.

Phosphorus levels in foliage (table 2) were affected only slightly by fertilization. The significantly lower P levels in the lower crown with added nitrogen probably reflect a "dilution effect." Nitrogen levels were well correlated with growth parameters, with slightly better correlations in the upper crown (table 3). Phosphorus concentrations, on the other hand, were poorly correlated with growth.

Table 3.—*Coefficients of determination (r^2) for linear regressions relating foliar nutrient levels and growth of young cottonwood trees*

Element and crown position	Diameter growth	Basal area growth	Height growth	Volume growth
Percent N				
Upper crown	0.82	0.87	0.52	0.88
Lower crown	.78	.75	.56	.77
Percent P				
Upper crown	.00	.04	.00	.04
Lower crown	.40	.39	.47	.43

DISCUSSION

Results show that nitrogen is the primary nutrient limiting growth on the site. Since phosphorus alone did not stimulate growth, soil phosphorus apparently is at an adequate level. In fact, analyses revealed that the level of extractable-P was slightly higher than is often observed on highly productive sites. Total soil nitrogen in the present study was 760 pounds per acre, as compared to about 2,000 pounds per acre on productive sites. Adding phosphorus alone probably enlarged the difference between soil N and P, resulting in an even greater imbalance of the two elements.

Few workers have demonstrated large growth responses in cottonwood stands. However, Martin and Carter *(10)* demonstrated large responses from nitrogen applied to cottonwood in the nursery. Blackmon and Broadfoot *(1)*, working with Commerce soil in the greenhouse, reported a slight growth response from nitrogen. Likewise, some European research *(6, 11)* has shown that nitrogen often limits the growth of poplars.

Foliar analyses also bear out the conclusion that nitrogen is limiting growth. First, foliar

N in both upper and lower crown positions was increased by N fertilization, while P levels were relatively unchanged. The generally high correlations of foliar N and growth also lend support to this position.

White and Carter *(14)* recommended sampling both upper and lower crown positions for foliar N and P determinations. Our data suggest that, for N, either position is satisfactory since r^2 values are essentially the same for both positions.

Other researchers *(12, 13, 14)* have suggested a nitrogen foliage level of 2 percent to be minimum for several species of poplars. Our results seem to support this proposed critical value. All treatments which included nitrogen boosted foliar N levels to over 2 percent in the upper crown (fig. 1). This foliage N/growth relationship is probably strongest on sites that are deficient in nitrogen and where growth is not severely limited by some other factor. According to Leyton *(8)*, growth and nutrient concentration are linearly and positively related only within the deficiency range. Nitrogen rate studies should yield additional information on this point.

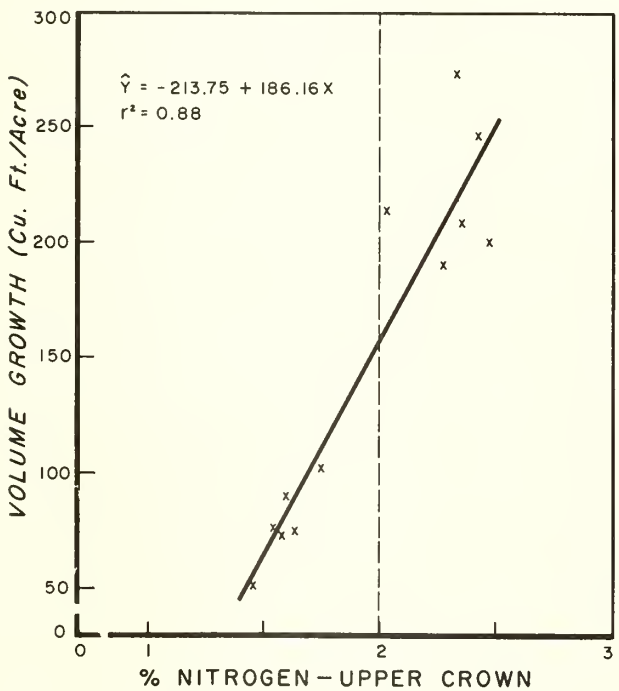

Figure 1.—*Total volume growth and nitrogen content of foliage in upper crowns of cottonwoods.*

The large growth increases in this pioneer investigation are the first field fertilizer responses reported for cottonwood on Misssissippi River Floodplain soils. Important questions about rates, sources, and frequency of application remain unanswered. For industrial firms requiring cottonwood fiber, the response obtained during the first year of the study is probably practical. If this response is of several years' duration, fertilizer application will become attractive for increasing growth of cottonwood on old-field sites in the Mississippi Delta.

LITERATURE CITED

1. Blackmon, B. G., and Broadfoot, W. M.
   1969. Lime, fertilizer cottonwood tests. Miss. Farm Res. 32(7): 6, 8.

2. Bonner, F. T., and Broadfoot, W. M.
   1967. Growth response of eastern cottonwood to nutrients in sand culture. USDA Forest Serv. Res. Note SO-65, 4 p. South. Forest Exp. Stn., New Orleans, La.

3. Broadfoot, W. M., and Ike, A. F.
   1968. Research progress in fertilizing southern hardwoods. *In* Forest fertilization—theory and practice, p. 180-184. Forest Fert. Symp. Proc. 1967. Tenn. Val. Auth. Nat. Fert. Develop. Center, Muscle Shoals, Ala.

4. Carter, M. C., and White, E. H.
   1970. The growth of cottonwood in Alabama. Highlights of Agric. Res. 17(1):6. Ala. Agric. Exp. Stn., Auburn.

5. Curlin, J. W.
   1967. Clonal differences in yield response of *Populus deltoides* to nitrogen fertilization. Soil Sci. Soc. Am. Proc. 31: 276-280.

6. Giulimondi, G.
   1961. The effects of fertilizing on young poplars in the nursery. Allulosa e carta 12(5): 27-30. Cited by For. Abstr. 23(1): 53.

7. Krinard, R. M.
   1971. 12 x 12 initial spacings in cottonwood plantations. USDA Forest

Serv. Tree Plant. Notes 22(4): 17-19.

8. Leyton, L.
1958. The relationship between the growth and mineral nutrition of conifers. *In* The physiology of forest trees, p. 330. (K. V. Thimann, ed.) N. Y.: Ronald Press.

9. McKnight, J. S., and Biesterfeldt, R. C.
1968. Commercial cottonwood planting in the southern United States. J. For. 66: 670-675.

10. Martin, J. W., and Carter, M. C.
1967. Nitrogen improves growth of *Populus deltoides* nursery stock. USDA Forest Serv. Tree Plant. Notes 18(3): 24-26.

11. Mayer-Krapoll, H.
1956. The use of commercial fertilizers —particularly nitrogen—in forestry. 111 p. N. Y.: Allied Chemical and Dye Corp.

12. Meiden, H. A. van der
1960. Handbook voor de populierenteelt. Ed. 3, 291 p. Arnhem, Ned.: Heidemij.

13. Mitchell, H. L., and Chandler, R. F., Jr.
1939. The nitrogen nutrition and growth of certain deciduous trees of northeastern United States. Black Rock Forest Bull. 11, 94 p.

14. White, E. H., and Carter, M. C.
1970. Relationships between foliar nutrient levels and growth of young natural stands of *Populus deltoides* Bartr. *In* Tree growth and forest soils, p. 283-294. Third N. Am. Forest Soils Conf. Proc. 1968. (C.T. Youngberg and C.B. Davey, ed.) Corvallis: Oregon State Univ. Press.

SOUTHERN FOREST EXPERIMENT STATION

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ECONOMICALLY ORIENTED PRODUCTION FUNCTIONS FOR SLASH AND LOBLOLLY PINE PLANTATIONS

Walter C. Anderson

SOUTHERN FOREST EXPERIMENT STATION

Tables present volumes per acre and size distributions for slash and loblolly pine plantations at ages 20, 25, and 30 years on medium and good sites. The information presented is necessary for economic decisions at planting time.

Investment decisions about planting pine for timber production require predictions of physical outputs, which, together with unit prices, determine the probable payoffs. Tables 1 and 2 show physical outputs per acre for unthinned plantations of slash and loblolly pine, the two most widely planted southern pine species.

Yield tables also contain physical outputs, but they present the would-be investor with many alternatives that do not relate to his problem. The tables presented here are easily understood and interpreted, and they provide sufficient information for investment decisions at planting time. Methods for making economic evaluations from the information in the tables are illustrated in "Investor's Guide to Converting Southern Oak-Pine Types." [1]

Values in table 1 are taken from slash pine yield tables prepared by Bennett and Clutter (table 4, p. 14-15).[2] Those in table 2 are from tables for loblolly pine developed by Lenhart (table 16, p. 73).[3]

These yield tables were desirable for several reasons. First, they represented plantations rather than natural stands. Second, data for them were gathered in enough plantations that the estimated value for any given cell is representative. Third, the tables indicated numbers of surviving trees by diameter class, as well as total volume. Diameter distributions are especially useful for economic analyses.

Tables 1 and 2 each give outputs for only two site classes, which are termed medium and good. These two classes account for about three-quarters of the area suitable for planting slash and loblolly pine. A more detailed breakdown is not needed by the average investor.

Instead of tree height at a specific age, site quality is defined in terms of volume growth

[1] Anderson, W. C., and Guttenberg, S. Investor's guide to converting southern oak-pine types. USDA Forest Serv. Res. Pap. SO-72, 10 p. South. Forest Exp. Stn., New Orleans, La. 1971.

[2] Bennett, F. A., and Clutter, J. L. Multiple-product yield estimates for unthinned slash pine plantations—pulpwood, sawtimber, gum. USDA Forest Serv. Res. Pap. SE-35, 21 p. Southeast. Forest Exp. Stn., Asheville, N. C 1968.

[3] Lenhart, J. D. Yield of old-field loblolly pine plantations in the Georgia Piedmont. Ph.D. diss., 98 p. Univ. Ga. 1968.

Table 1.—*Physical output per acre from unthinned slash pine plantations*

Production period (years)	Volume of wood	Surviving trees	Diameter class (inches)										
			4	5	6	7	8	9	10	11	12	13	14
	M cu. ft.	*Number*	*– – – – – Cumulative number of trees (percent) – – – – –*										
			MEDIUM QUALITY SITE										
20	1.6	300	100	97	90	75	54	31	11	1			
25	1.9	230	100	99	95	87	73	55	34	15	4		
30	2.1	200		100	98	92	82	68	49	30	12	2	
			GOOD QUALITY SITE										
20	2.3	300	100	99	94	84	68	47	25	8			
25	2.7	230		100	98	92	82	67	49	29	13	3	
30	3.0	200		100	99	96	88	78	62	44	26	10	1

Table 2.—*Physical output per acre from unthinned loblolly pine plantations*

Production period (years)	Volume of wood	Surviving trees	Diameter class (inches)									
			5	6	7	8	9	10	11	12	13	14
	M cu. ft.	*Number*	*– – – – Cumulative number of trees (percent) – – – –*									
			MEDIUM QUALITY SITE									
20	2.2	480	100	95	83	62	36	13	1			
25	3.0	450	100	98	90	74	53	30	11	1		
30	3.6	430	100	99	92	80	63	42	22	6		
			GOOD QUALITY SITE									
20	3.1	410	100	99	94	82	62	38	15	1		
25	4.2	380		100	98	91	78	59	37	16	3	
30	4.9	350		100	99	95	85	70	51	31	13	2

per acre per year for the rotation. Slash pine sites growing an average of 75 cubic feet are classed as medium, and those growing approximately 110 cubic feet as good. Medium and good sites for loblolly pine are those growing about 120 and 155 cubic feet, respectively.

Although total output is constrained by the productive potential of the site, an investor can influence the form of the output by varying tree spacing. If his objective is to grow pulpwood for maximum volume, he will select a close spacing because total output is greatest at a relatively close interval. On the other hand, if his goal is high unit value, he will choose relatively wide spacing. With fewer stems per acre, trees grow faster in diameter, reaching a large size sooner. For large trees, cost of harvesting is lower per unit volume than for small ones, and since bole quality is correlated with tree size a greater proportion of the bole can be used in high-value products. Of course, with extremely wide spacing, the loss in total volume growth is excessive, and natural pruning is delayed, reducing quality of individual stems.

An initial spacing of 8 by 8 feet (680 trees per acre) was assumed in preparing tables 1 and 2. This spacing is a compromise between total yield and tree size that gives high monetary returns. Where outputs for this spacing were not available from yield tables, adjustments were necessary. In some instances, points had to be interpolated or curves extended because yield tables were based primarily on plantations planted at 6 by 6 feet. In making adjustments, data from available growth and yield studies were used as guides.

The tables show the probable numbers of survivors at several harvesting ages. Differences in volumes and tree sizes between the two species largely reflect differences in stocking levels. Being more tolerant than slash pine

and less subject to fusiform rust, loblolly has less mortality. In addition, loblolly pine height growth slows later than slash, and cubic-foot volume growth culminates at a later age for loblolly.

In preparing tables 1 and 2, volumes were converted to cubic feet, where they were not already in this measure. They are expressed in this unit because, unlike cords and board feet, it is free from identification with any particular product. More and more firms are operating processing facilities where they convert each tree section to its most profitable use. No longer is there a clear division between pulpwood and saw-log trees. An independent measure such as cubic feet is, therefore, in keeping with current trends and future possibilities.

Tables 1 and 2 show physical output per acre at harvest ages of 20, 25, and 30 years in cubic-foot volume of wood, number of surviving trees, and percentage distributions of cumulative numbers of trees by 1-inch d.b.h. classes. Volumes per acre are the sums of volumes in boles up to a 4.0-inch top, d.o.b., of trees 4.6 inches d.b.h. and larger.

From the cumulative percentage of stems above any selected d.b.h. class limit, is is possible to find the percentage of trees in a particular d.b.h. class. Merely subtract the cumulative percentage figure for the next highest class from that for the class of interest. For example, the proportion of slash pine stems in the 8-inch d.b.h. class at age 20 on medium sites is 54 — 31 = 23 percent. Further, this figure can be converted into the number of trees in the class by simply multiplying it by the total number of trees in the stand ($0.23 \times 300 = 69$ trees).

The production functions show that in as little as 20 years a substantial proportion of the trees in unthinned stands are of relatively large diameter. This is indicated by the diameter classes that contain at least one-half of the stand.

Calculations showed that for both species on medium sites, the sizes of the largest trees containing half of the cubic-foot volume are at least 9 inches d.b.h. at 20 years and 10 inches d.b.h. at 25 years. At 30 years, half the volume is in slash pines 11 inches d.b.h. and larger and in loblolly pines 10 inches and larger. On good sites, trees grow more rapidly in diameter. For both species on good sites, half the volume is in trees 11 inches and larger at age 25.

The volumes and tree distributions shown in tables 1 and 2 can be attained for unthinned loblolly and slash pine plantations in which mortality has been average and in which spatial distribution is good. To attain the outputs shown, it is essential that these conditions be met. Mortality, of course, is usually heaviest in the first growing season after planting and then declines. At about age 5, it would be desirable to examine the stand for fusiform rust and for the level of stocking with an eye toward controlling density by precommercial thinning, if necessary, to reach the outputs reported herein.

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BURNING TO REDUCE UNDERSTORY HARDWOODS IN THE ARKANSAS MOUNTAINS

Herbert A. Yocom

SOUTHERN FOREST EXPERIMENT STATION

Three burns in a 60-year-old shortleaf pine stand in Arkansas reduced the number of 5.5-inch and smaller understory hardwoods. More small than large hardwoods were killed.

Dense hardwood understories in the Ouachita Mountains of Arkansas usually must be controlled to satisfactorily regenerate pines *(6)*. Burning for this purpose has been successful in southern Arkansas *(3)* and other locations in the South *(1, 5, 7)*. In some instances burning also has improved growth of the pine overstory *(4)*. This note describes effects of several burning treatments on hardwood numbers, establishment of pine reproduction, and diameter growth of merchantable pines in the Ouachita Mountains.

METHODS

The study was installed in a 60-year-old shortleaf pine *(Pinus echinata* Mill.) stand. Pines averaged about 11 inches d.b.h. and contained about 95 square feet of basal area per acre. Most hardwoods were small and in the understory. About two-thirds were oaks *(Quercus* spp.), hickory *(Carya* spp.), or gums *(Nyssa sylvatica* Marsh. and *Liquidambar styraciflua* L.). The topography was gently rolling with most slopes less than 10 percent. Shortleaf pine site index at age 50 averaged 54 feet *(8)*.

There were 16 1-acre plots arranged in four blocks. One plot in each block received no treatment, one plot received one summer burn, another two, and the fourth three burns. The second burn was made 1 year after the first, and the third burn was applied 3 years after the second. Fires were generally light to moderate; some resetting was necessary to achieve complete coverage.

Sample pines and hardwoods on each plot were measured or inventoried 4 years before the first treatment and 2 years after the final treatment. These data permitted computation of pine growth and changes in the number of understory hardwoods for a 10-year period, 1959-1968, within which the treatments were applied. Any variation in pine growth or change in hardwood numbers during this period can be attributed to the effects of treatments.

Twenty overstory pines on each plot were measured in the first inventory, numbered, and remeasured in the second inventory. Pine seedlings on 20 random milacres per plot were tallied 2 years after the end of the 10-year period to assess possible differences in seedling establishment.

There were very few hardwoods on the plots over 5.5 inches in diameter at a point 6 inches above ground level. Those 5.5 inches and smaller were tallied on a permanent strip 6 feet wide and 220 feet long laid out diagonally across the center of each plot. Supplementary data was taken on tagged hardwoods on or near these plot sampling strips to determine treatment effects by four species groups and by three size classes. The species groups were red oaks, white oaks, gums, and all others. The size groups were 0.0 to 1.5 inches d.b.h., 1.6 to 3.5, and 3.6 to 5.5 inches.

Analyses of variance to test differences for statistical significance were computed for total number of hardwoods, decrease in total number of hardwoods, decrease in total number of hardwoods by several size classes, and pine diameter growth and reproduction. All tests for significance were at the 0.05 level.

RESULTS

Multiple burns reduced the number of hardwoods and appear promising for preparing seedbeds for natural regeneration, provided the pine overstory is thinned somewhat from that present in this study. The mean numbers of hardwood stems on sampling strips at the end of the 10-year period were 147, 126, 86, and 39 for no burn, one burn, two burns, and three burns, respectively. Duncan's multiple range test showed a significant difference between the means for no burning and three burns. The mean decreases in the total number of hardwood stems per strip were 3.8, 1.5, 44.2, and 89.0 for the above treatments. These differences are not statistically significant. Analysis by stem size class showed that decreases in stem numbers were not significant for 0.5 inch and smaller stems but were significant for the 0.6- to 5.5-inch stems. Numbers of the smallest stems increased by 14.2 percent, while numbers of the largest decreased by 33 percent. Disappearance of small stems was more than offset by sprouting, which sometimes resulted in multiple stems where there had been a single stem originally.

Data by species and size of stem showed a difference among treatments in survival of hardwood stems at the end of the 10-year period. The percentages were 100, 77, 73, and 17 for no burn, one burn, two burns, and three burns, respectively. There were no significant differences among species groups. Survivals by size class varied significantly and were 57, 66, and 77 percent alive for stems 0.0 to 1.5 inches, 1.6 to 3.5 inches, and 3.6 to 5.5 inches in diameter.

Treatments had no effect on pine growth, which averaged 1.24 inches in d.b.h. for the 10-year period. Excess moisture during the last four growing seasons of the study, 1965-1968, when most of the growth acceleration was expected, my have precluded treatment effects. Precipitation for May through September averaged 33 percent more each year than the 1944-1968 mean. Some studies have shown that pine growth response to hardwood understory removal is negligible during years of normal or excess growing-season rainfall *(2)*, but other studies have shown just the opposite *(4)*.

Four years after the last burn, pine reproduction averaged 962 seedlings per acre on plots burned twice and 1,412 on those burned three times, compared to none on the unburned and once-burned plots. There were wide variations within treatments, however, and the differences were not statistically significant. Any increases in seedling establishment due to burning were nullified by competition from the heavy pine overstory that caused most of the little pines to die during the first year after germination.

LITERATURE CITED

1. Brender, E. V., and Copper, R. W.
1968. Prescribed burning in Georgia's Piedmont loblolly pine stands. J. For. 66: 31-36.

2. Brinkman, K. A., and Smith, R. C.
1968. Managing shortleaf pine in Missouri. Mo. Agric. Exp. Stn. Bull. 875, 35 p.

3. Grano, C. X.
1970. Eradicating understory hardwoods by repeated prescribed burning. USDA Forest Serv. Res. Pap. SO-56, 11 p. South. Forest Exp. Stn., New Orleans, La.

4. Grano, C. X.
1970. Small hardwoods reduce growth of pine overstory. USDA Forest Serv. Res. Pap. SO-55, 9 p. South. Forest Exp. Stn., New Orleans, La.

5. Lotti, T., Klawitter, R. A., and LeGrande, W. P.
1960. Prescribed burning for understory control in loblolly pine stands of the Coastal Plain. USDA Forest Serv. Southeast. Forest Exp. Stn., Stn. Pap. 116, 19 p.

6. Maple, W. R.
1965. Shortleaf pine stands five years after seedfall on prepared sites. USDA Forest Serv. Res. Note SO-27, 2 p. South. Forest Exp. Stn., New Orleans, La.

7. Trousdell, K. B., and Langdon, O. G.
1967. Disking and prescribed burning for loblolly pine regeneration. J. For. 65: 548-551.

8. USDA Forest Service.
1929. Volume, yield, and stand tables for second-growth southern pines. USDA Misc. Publ. 50, 202 p.

SOUTHERN FOREST EXPERIMENT STATION

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REPLACEMENT PLANTING WITH POTTED SOUTHERN PINES ON RESEARCH PLOTS

R. C. Schmidtling [1]

SOUTHERN FOREST EXPERIMENT STATION

Replacing first-year losses with potted seedlings seems feasible in southern pine research plantings. Slash, longleaf, and loblolly pine seedlings potted for several months before planting generally grew as well, were as resistant to wind damage, and survived better in the field than seedlings that were bar-planted 1 year earlier.

High mortality on some plots in experimental plantations often limits interpretation of diameter and volume data. Replacing the first-year losses with bar-planted stock, however, has been unsuccessful because the replacements usually do not overcome the initial size advantage of the originals and are often suppressed *(1, 4)*. Initial height growth of longleaf pines *(Pinus palustris* Mill.) has been greatly improved in experimental plantings by potting the seedlings in 1-quart milk cartons after they are lifted in the nursery, holding them for a few months, and outplanting them with their potting soil intact *(3)*.

This paper describes the results of replacing first-year mortality in longleaf, slash *(P. elliottii* Engelm.), and loblolly *(P. taeda* L.) pines with potted seedlings.

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MATERIALS AND METHODS

The plantation was established in the spring of 1960 to test the effects of intensive culture on the growth of longleaf, slash, and loblolly pines *(2)*. Second-growth longleaf occupied the site before clearcutting in 1958-59. The soils, upland fine sandy loams in the Bowie and Shubata series, are considered relatively infertile *(2)*.

Treatments were: (1) control, with no site preparation or subsequent treatment, (2) cultivation, including intensive site preparation and disking several times a year for 3 years after outplanting, and cultivation plus fertilization at rates of (3) 1,000 pounds, (4) 2,000 pounds, and (5) 4,000 pounds of 10-5-5 NPK per acre. Fertilizer was broadcast at the beginning of the second growing season.

The original experiment included seedlings from parent trees of high and average specific gravity, but the two populations are treated

as one for the purposes of this report. Since the three fertilizer treatments produced similar growth responses, their results were combined within species, reducing the number of treatments in the present analysis to three: (1) control, (2) cultivation, and (3) cultivation and fertilization.

Plots were 100-tree squares surrounded by two rows of border trees and arranged in a randomized complete block design of four replications for each species.

First-year mortality averaged nearly 20 percent and was especially heavy on the control plots (table 1). Dead seedlings were replaced at the beginning of the second growing season with material of the same source as the original planting.

Table 1.—*Survival of original and replanted seedlings after one and nine growing seasons*

Species and treatment	Trees planted	First-year survival	Ninth-year survival	
			Originals	Replants
	Number	*– – – Percent – – –*		
Loblolly pine				
Control	800	77.3	75.5	93.8
Cultivated	800	86.5	85.1	[1] 99.1
Cultivated and fertilized	2,400	89.2	87.0	94.0
Slash pine				
Control	800	65.4	64.3	[1] 94.7
Cultivated	800	80.5	75.6	[1] 97.3
Cultivated and fertilized	2,400	79.7	74.4	[1] 93.8
Longleaf pine				
Control	800	74.8	54.9	[1] 82.2
Cultivated	800	83.4	68.0	[1] 86.4
Cultivated and fertilized	2,400	82.7	74.8	[1] 84.7
Total	12,000	81.5	75.5	91.4

[1] Survival of replants and originals differ significantly at 0.05 level.

Replacement seedlings were lifted and root-pruned in February 1961, potted in 1-quart milk cartons, maintained in a lath house, and outplanted in mid-May.

Survival and heights were measured 9 growing seasons after the original planting. Since extensive hurricane damage occurred in the Fall of 1969, 10-year data were taken only on survival, d.b.h., and wind damage. Trees tallied as damaged had broken main stems, were uprooted, or were leaning more than 30° from vertical.

Data for the replacement seedlings (replants) were separated from those for the original seedlings (originals) and compared by paired "t" tests on plot bases. Differences exceeding the 0.05 level of probability were considered significant.

RESULTS AND DISCUSSION

The success of potted replacements is evident from 9-year survival data (table 1). For all treatments and species, survival of replants was much higher than that of originals, though the difference was not statistically significant for loblolly control and fertilized treatments. Survival of originals ranged from 55 percent of longleaf controls to 87 percent of cultivated and fertilized loblolly, whereas that of replants ranged from 82 percent of longleaf controls to over 99 percent in cultivated loblolly.

In spite of the 1-year difference in age, heights of replants and originals differed little 9 years after plantation establishment (fig. 1). The replants were significantly shorter than the originals in only two of the nine treatment/species combinations. Fertilized slash replants were about 2 feet shorter than originals, and fertilized longleaf less than a foot shorter. In three instances, loblolly control, loblolly cultivated, and longleaf cultivated, the replants averaged taller than the originals. Cultural conditions in most experimental plantations would approximate those in the controls or the cultivated only treatments. Under these conditions, replants were no smaller than originals of any species. Potting and careful handling of replants appears equivalent to 1 year of height growth in the field.

The pattern for 10-year d.b.h. was the same as for 9-year height. Replants were significantly smaller than originals in only two species/treatment combinations, the fertilized slash and fertilized longleaf.

The effects of potting on the shape of the root system and subsequent windfirmness may be of some concern. On August 17, 1969, Hurricane Camille subjected the trees to winds reportedly approaching 200 miles per hour in

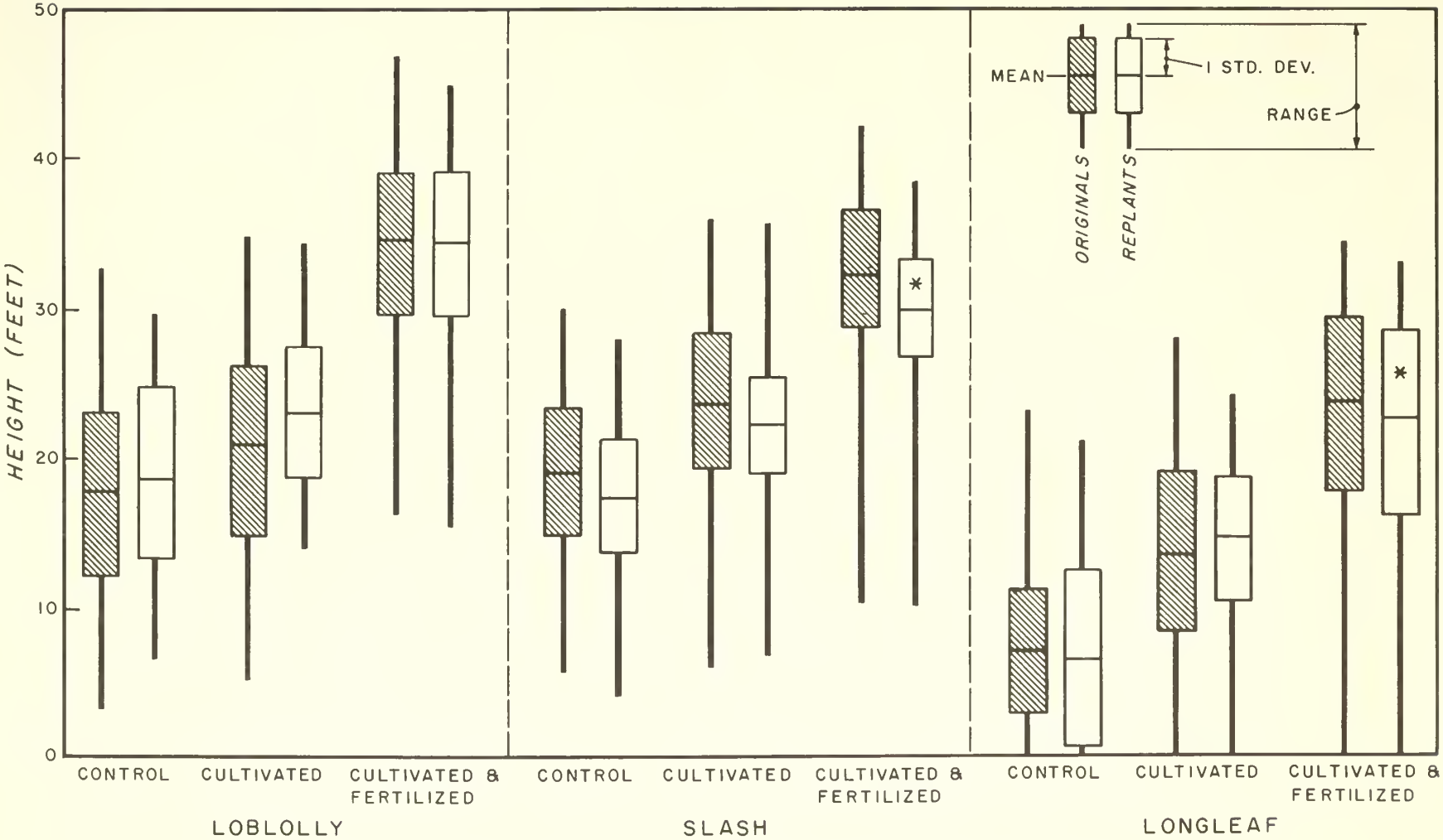

Figure 1.—*Heights of replants and originals at plantation age 9. * indicates replants that were significantly smaller than comparably treated originals at 0.05 level.*

gusts. Overall, damage varied directly with height but inversely with crown closure. The most common form of damage was leaning more than 30°.

Loblolly and longleaf replants tended to be slightly more susceptible to wind damage than originals (fig. 2), but the difference was significant in only one instance, the fertilized loblolly, where 38 percent of replants and 26 percent of originals were damaged. Slash pine replants fared somewhat better than originals in all treatments. The small differences that were observed are of doubtful importance in less than hurricane-force winds.

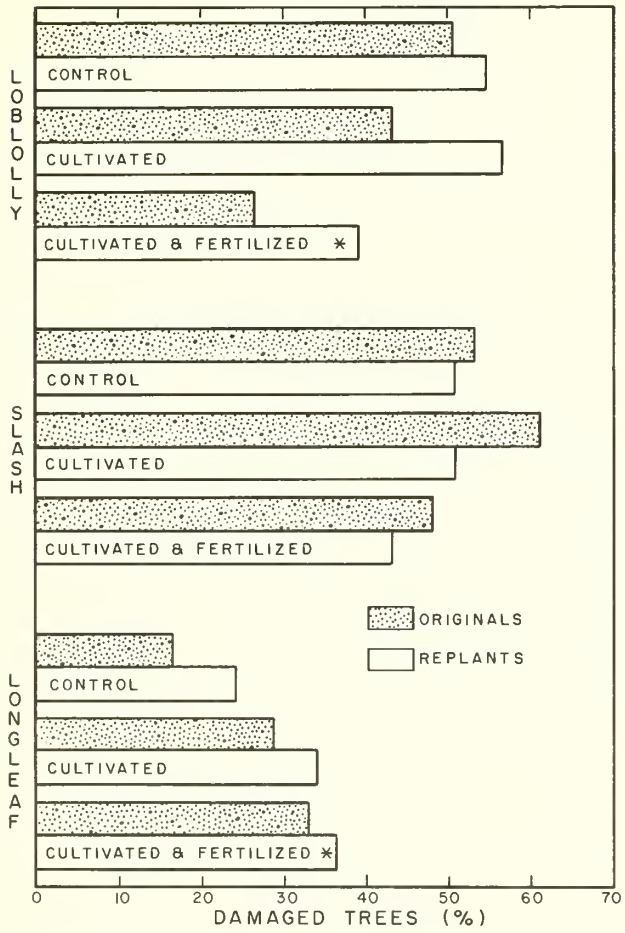

Figure 2.—*Wind damage to replants and originals by Hurricane Camille. * indicates replants that suffered significantly more damage than comparably treated originals at 0.05 level.*

Although replacing first-year mortality with potted stock during the second growing season would be too costly for general forestry practice, it appears feasible for experimental plantations of southern pines. Replacement helps to maintain uniform competition, eliminating unwanted variation among study plots. Where replants perform differently from originals, data on them could be separated in the analysis, and the replants could be removed in the first thinning.

LITERATURE CITED

1. Schultz, A. J.
   1961. A second report on interplanted slash pine. USDA Forest Serv. Southeast. Forest Exp. Stn. Res. Note 154, 2 p.
2. Smith, L. F., and Schmidtling, R. C.
   1970. Cultivation and fertilization speed early growth of planted southern pines. USDA Forest Serv. Tree Plant. Notes 21(1): 1-3.
3. Smith, L. F., Snyder, E. B., and Scarbrough, N. M.
   1963. Care of pine seedlings used in breeding at Institute of Forest Genetics. USDA Forest Serv. Res. Note SO-2, 4 p. South. Forest Exp. Stn., New Orleans, La.
4. Wakeley, P. C.
   1968. Replacement planting of southern pines unsuccessful. USDA Forest Serv. Res. Note SO-85, 4 p. South. Forest Exp. Stn., New Orleans, La.

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HORIZONTAL PLANTING OF GREEN ASH CUTTINGS LOOKS PROMISING

H. E. Kennedy, Jr. [1]

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Green ash cuttings made from 1-0 seedlings sprouted and grew exceptionally well when planted horizontally at depths of 1 and 3 inches. Sprouts from 10- and 14-inch cuttings grew better than those from 6-inch cuttings.

Landowners are seeking ways to regenerate green ash cheaply because of its desirable wood, satisfactory growth in plantations, and good performance on periodically flooded areas. The cost of placing cuttings horizontally in furrows might be sufficiently low to make commercial planting practical, and results reported here indicate that this technique can be successful.

METHODS

This study was done in the experimental nursery at the Southern Hardwoods Laboratory. Soil is moderately-well-drained silt loam.

Cuttings were taken from 1-0 green ash seedlings obtained from the Mississippi Forestry Commission. One cutting was made from each seedling; root collars were included. Cuttings were made in January, wrapped in damp peat moss and plastic, and stored in a cooler at 2 to 4° C. until planting.

On April 7, 1971, cuttings 6, 10, and 14 inches long were planted end to end in hoed furrows 1, 3, and 6 inches deep. Approximately 60 inches of cuttings were planted in each row; four 14-inch, six 10-inch, or ten 6-inch lengths. Extra cuttings planted in the same manner at the test site were excavated periodically to study root development.

The experimental design was a randomized complete block with a factorial arrangement of treatments. There were three replications of each of the nine treatment combinations (3 cutting lengths × 3 planting depths). Treatments were randomly assigned to rows within blocks. Each row constituted a plot. Variables analyzed were number of sprouts, percentage of cuttings that sprouted, average heights, and diameters at groundline. Means were com-

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pared with Duncan's new multiple range test. Survival percentages were transformed to arcsin before analysis. Sprouting data were transformed to the square root of the number of sprouts plus 0.5, a method described by Steel and Torrie.[2]

RESULTS AND DISCUSSION

About 1 month after planting, the cuttings began to sprout and form roots. Roots developed first at the root collar end of the cutting, but during the growing season they were formed at points along the entire cutting. By the end of the growing season, each cutting had a large, well-developed root system (fig. 1).

Five combinations of planting depth and cutting length sprouted particularly well: 1-inch depth and 6-inch cutting (1×6), 1×10, 1×14, 3×10, and 3×14 (table 1). Duncan's multiple range test showed that 3×14 and 1×10 were significantly better than all combinations except 1×6 and 1×14. All lengths sprouted poorly at the 6-inch depth. Six-inch cuttings sprouted poorly at the 3-inch depth. All cuttings performed well at the 1-inch depth (table 1).

There were no significant differences in root-collar diameters by treatment when all sprouts were considered, but treatments significantly affected diameter of the five largest sprouts per row (table 1). The 3×14 treatment had the largest average diameter, but it was not significantly larger than that for 1×10, 1×14, 3×10, 6×6, or 6×10. It is apparent from table 1 that there was not a large difference among treatments with respect to diameter growth.

Height growth in all treatments was good. Many individual sprouts were more than 5 feet tall after one growing season, and some exceeded 6 feet.

Average heights of all sprouts differed significantly among treatments with heights ranging from 2.10 feet in the 1×6 treatment to

[2] Steel, R. G. D., and Torrie, J. H. Principles and procedures of statistics. 481 p. McGraw-Hill Book Co., Inc. 1960.

Figure 1.—*Typical sprouts and root systems at end of one growing season. All cuttings were planted at 1 inch depth; 6-inch length (left), 10-inch (center), and 14-inch (right).*

Table 1.—*Performance of horizontally planted green ash cuttings after one growing season*

Planting depth and cutting length	Proportion sprouting	Sprouts per row [1]	Diameter, all sprouts	Diameter, 5 largest sprouts	Height, all sprouts	Height, 5 largest sprouts
	Percent	*Number*	*Inch*	*Inch*	*Feet*	*Feet*
1×6	86.7 a,b [2]	13 a	0.45 b	0.56 b	2.10 c	2.90 b
1×10	100.0 a	12 a,b	.55 a,b	.65 a,b	2.46 b,c	2.11 b
1×14	83.3 a,b	8 a,b,c	.54 a,b	.63 a,b	2.49 b,c	3.07 b
3×6	50.0 c,d	7 b,c	.53 a,b	.58 b	2.50 b,c	2.83 b
3×10	77.7 b,c	8 a,b,c	.55 a,b	.63 a,b	2.82 a,b	3.23 b
3×14	100.0 a	9 a,b	.60 a	71 a	3.11 a,b	3.87 a
6×6	23.3 d	2 d	.62 a	.62 a,b	3.08 a,b	3.08 b
6×10	55.7 b,c,d	4 c,d	.60 a	.62 a,b	3.21 a	3.35 a,b
6×14	41.7 c,d	2 d	.56 a	.56 b	2.73 a,b,c	2.73 b

[1] A row is approximately 60 inches of cuttings in a hoed furrow. All data based on average of three replications.

[2] Within columns, means followed by the same letter do not differ significantly at the 0.05 level.

3.21 feet in the 6×10 treatment (table 1). Heights of the five largest sprouts per row ranged from 2.73 feet in the 6×14 treatment to 3.87 in the 3×14 treatment (table 1). The deeper planting depths did not affect growth, but resulted in fewer sprouts.

The 1- and 3-inch planting depths with longer cuttings gave best overall sprouting and growth, with the 3×14 treatment the best.

In plantings such as this, the question of advantages and disadvantages of multiple sprouting arises. Most treatments had multiple sprouting, which probably would be an advantage in close-spacing, short-rotation plantings such as advocated for sycamore. For plantations at more normal spacings, multiple sprouts may be a liability because of reduced growth of one desirable sprout at each planting spot. From this study there would be no way to choose one treatment over another on the basis of multiple sprouting.

Horizontal planting of green ash cuttings looks promising. When the method is perfected, it may be applicable to a wide variety of sites. It should permit highly mechanized planting. Green ash is tolerant, and it probably could be underplanted, eliminating expensive site preparation and cultural treatments. Since the species can be reproduced vegetatively from cuttings, a tree improvement program similar to the one for cottonwood may be feasible.

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ANIMAL DEPREDATIONS ON SPOT-SEEDED YELLOW-POPLAR IN CENTRAL TENNESSEE

T. E. Russell [1]

SOUTHERN FOREST EXPERIMENT STATION

On forested sites of the Cumberland Plateau, screen protection of seedspots tripled yellow-poplar (Liriodendron tulipifera *L.) seedling establishment. In a number of trials, however, sufficient exposed seed escaped damage to yield fair stocking. Thus it appears that unprotected seed can provide acceptable stands but will require a large number of seedspots per acre.*

Additional keywords: *Liriodendron tulipifera,* direct seeding, regeneration of hardwoods.

Yellow-poplar is an excellent species for many sites in central Tennessee, but in some places high-grading and wildfires have eliminated all seed trees. This species can be planted readily when prospects for natural regeneration are poor (Russell and others, 1970). Direct seeding would be a useful option and might be more practical than planting where heavy logging slash, steepslopes, or rocky soils restrict machine operation and make even hand planting difficult.

Since there have been few attempts to direct-seed yellow-poplar, the factors that determine success are largely unknown. In North Carolina, seedspot protection increased establishment and stocking by reducing animal depredations (Sluder and Rodenbach, 1964). Animals have also damaged seed in tests at Sewanee, and they were not deterred by a repellent that has been used extensively with the southern pines.

The study reported here investigated animal hazards in two cover types of the Cumberland Plateau. It also compared fall and spring sowing under three levels of seedspot protection. Trials were repeated for three consecutive years at 10 widely dispersed locations near Sewanee.

METHODS

Five of the installations were on slopes of the Plateau escarpment in areas referred to

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locally as coves. Five were in shallow, U-shaped hollows on top of the Plateau.

Soils in the coves are of the Allen or Jefferson series, developed in deep, bouldery colluvium derived from the sandstone and shale caprocks of the Plateau. They formerly supported fine hardwoods, ranging from oak-hickory to mixed mesophytic types on favorable aspects, but many stands have been depleted by overcutting. Plateau hollows have Hartsells and Ramsey soils on the slopes and stringers of local alluvium along the bottoms. Timber here consists mainly of fair-quality oaks and hickories with an occasional blackgum, red maple, or yellow-poplar.

These areas have been logged repeatedly and were last cut within the past 15 years. Since the main aim in the research was to define the potential for animal damage, residual hardwoods were not deadened. To do so would have initiated a succession of herbaceous vegetation and hardwood seedlings, resulting in a radically differing ground cover for each yearly trial.

Treatments were replicated five times in a completely randomized split-plot design, the five installations for each cover type being major plots. Each major plot was in a different cove or hollow, and was at least 0.5 mile from all other installations and from radically different cover types such as cultivated areas or old fields. Season-of-sowing and protection treatments were applied to six subplots at each location. Subplots contained 16 seedspots, spaced about 6 feet apart. Results were expressed as percent of seedspots disturbed; as the number of seedlings obtained per 100 seeds sown (i.e., tree percent); and as initial stocking, or the proportion of spots producing one or more seedlings. Differences were tested by analysis of variance after arcsine transformation, separately for each year. Data from a preliminary test in the spring of 1964 were not analyzed but provided additional information and are summarized here.

The preliminary sowing determined if the protective screens used would exclude animals and if seed loss or damage could be reliably detected. The study was then continued for 3 additional years, with unstratified seed being sown in November and stratified seed sown in March for each annual trial. The same seedlot was used for a single fall-spring series, but different lots were sown each year.

To check on the need for protection from various classes of animals, seedspots on randomly selected subplots were covered with ¼-inch-mesh hardware cloth or with 1-inch-mesh wire screens, or were left completely exposed. The screens, which were in the shape of cones or domes, were held in place with wire staples driven into the ground (Russell and Mignery, 1966). After the hardwood litter had been removed, 50 seeds were pressed into the surface of the mineral soil on each spot. The same subplots were used for all annual trials, any seed or seedlings left from the previous year being removed by raking.

RESULTS

Seedspot Depredations

Exposed spots were damaged heavily in all annual seedings (table 1). Screens of 1-inch mesh reduced losses appreciably only in 1965-1966, when depredations to exposed seed were also lighter than in other years. This level of protection excluded squirrels and other large animals but admitted smaller seedeaters such as mice. Since losses were almost as great as on open spots, smaller forest animals evidently fed freely. The ¼-inch screens significantly (0.01 level) limited robberies in all years—seed was damaged only on a few plots where animals burrowed under the screens.

Significantly more seedspots were disturbed on fall- than on spring-seeded plots in 1964-

Table 1.—*Seedspot disturbance by animals and seedspot stocking (data for fall and spring combined)*

Observation and type of seedspot screen	Year of test		
	1964-1965	1965-1966	1967-1968
	– – – Percent – – –		
Spots robbed			
None	98	65	81
1-inch mesh	98	54	82
¼-inch mesh	1	0	2
Stocking [1]			
None	36	43	46
1-inch mesh	38	54	50
¼-inch mesh	76	73	80

[1] Percent of seedspots that produced one or more seedlings.

1965 and in 1965-1966, although differences in the first year were small. For all years, depredations averaged 80 percent in the coves and 79 percent in the hollows. Differences between sites, or their interactions with season of sowing and protection, were not significant in any year.

Thus, moderate to heavy losses of seed can be expected on the Cumberland Plateau. Animal pressures may vary from year to year, but no strong cyclical pattern was evident in this study.

Seedling Establishment

Results expressed as tree percents paralleled those based on depredations. However, seedling establishment is influenced by seed quality and weather as well as by seed losses. Over the 3 years, tree percents averaged 1.3 on exposed seedspots and 1.4 on spots protected with 1-inch mesh; year-to-year variation was small. Protection with ¼-inch mesh screens yielded significantly better catches, averaging 4.1 percent. Spring seeding was superior to fall only in 1964-1965, when tree percents were 3.2 in spring and 1.6 in fall.

Gross normal germination of seedlots sown in the three annual trials averaged 21 percent in the laboratory. In the field, germination under ¼-inch mesh screens was much poorer, averaging less than one-fourth the potential indicated by laboratory tests.

With the spring trial of 1964 included, ability of seedlings to survive the first summer was evaluated in 4 consecutive years. Average survival was 54 percent and differed little between exposed and protected seedspots. Browsing animals do not appear to be a serious threat to newly germinated yellow-poplar on the Cumberland Plateau. Competition from residual timber and brush presumably caused most losses. Yellow-poplar seedlings are intolerant, and survival should be considerably better where unwanted hardwoods are removed promptly.

Seedspot Stocking

Stocking based on total field germination averaged 42 percent on exposed seedspots, 47 percent under 1-inch screens, and 76 percent under ¼-inch mesh screens. Excluding animals significantly increased stocking in all years. Stocking was better on spring- than on fall-seeded plots in 1964-1965—the only significant effect, other than that of protection, in three annual trials. On plots seeded in spring 1964, stocking ranged from 70 percent under partial protection to 95 percent under complete protection, a reflection of the superior seed sown in this preliminary trial.

If each season of sowing at each location, including spring 1964, is considered a separate test, the study comprised 70 small trials. Stocking achieved illustrates the degree of success attainable with unprotected and with protected seed:

Proportion of trials yielding initial seedspot stocking of:	Stocking under—	
	No protection	¼-inch-mesh screen
	– Percent –	
65 percent or better	24	77
50 percent or better	56	88
35 percent or better	64	94

Stocking was 65 percent or better in 77 percent of the trials where seed was fully protected, while unprotected spots yielded this level of success only 24 percent of the time. Even with exposed seed, stocking was 50 percent or higher in more than half the trials and 35 percent or more in almost two-thirds of the trials.

DISCUSSION

Foraging animals can limit yellow-poplar spot seeding on the Cumberland Plateau. Risks are apparently similar on two characteristic sites. In 2 of the 3 years, depredations were lighter in spring than in fall, but establishment and stocking were better in only 1 year. Season of sowing is probably not critical in central Tennessee.

Although residual hardwoods were not deadened, conditions for seedling establishment were comparable to those where hardwoods are controlled at the time of seeding or as soon as a catch is obtaind. Similar animal pressures would probably occur on small tracts surrounded by an intact stand, even if hardwoods were removed before seeding. Clearing extensive areas would have a more drastic effect on animal populations, particularly if ground vegetation were eliminated through mechanical site preparation.

Seedling establishment was better than might have been expected, considering the widespread foraging. Consistently superior results where animals were excluded, however, demonstrate that protection can greatly reduce the numbr of seedspots needed to achieve a specified stocking. Because of their high cost, mechanical devices are impractical for general use. The ideal solution would be to develop an economical and environmentally acceptable repellent.

While seed protection is desirable, spot sowing appears efficient enough to warrant trials with untreated seed in other regions and on a variety of sites. For best germination, yellow-poplar seeds should be covered with about ⅛-inch of mineral soil (Sluder and Rodenbach, 1964), and competing vegetation must be controlled to ensure good survival.

LITERATURE CITED

Russell, T. E., Loftus, N. S., Mignery, A. L., and Smalley, G. W.
1970. Planting yellow-poplar in central Tennessee and northern Alabama. USDA For. Serv. Res. Pap. SO-63, 17 p. South. For. Exp. Stn., New Orleans, La.

Russell, T. E., and Mignery, A. L.
1966. Wire staples for holding down seedspot screens. J. For. 64: 757.

Sluder, E. R., and Rodenbach, R. C.
1964. Yellow-poplar direct seeding in the North Carolina Piedmont. USDA For. Serv. Res. Note SE-25, 2 p. Southeast. For. Exp. Stn., Asheville, N. C.

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1973

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SUMMER FALLOWING IMPROVES SURVIVAL AND GROWTH OF COTTONWOOD ON OLD FIELDS

James B. Baker and B. G. Blackmon [1]

SOUTHERN FOREST EXPERIMENT STATION

Fallowing an old-field site during the summer prior to planting and applying a herbicide in September improved survival and growth of eastern cottonwood cuttings. Summer fallowing without applying herbicide also improved height growth of cottonwood through age 2. Deep plowing and cover cropping, alone or in combination, did not influence growth or survival during the first year after planting.

Additional keywords: *Populus deltoides*, site preparation, Johnson grass.

Survival and growth of planted eastern cottonwood *(Populus deltoides* Bartr.) are often poor on abandoned fields in the Mississippi Delta. These fields usually have compacted, nutrient-depleted surface soils and an abundance of grasses and other herbaceous vegetation. To improve establishment and growth of commercial hardwood species on these sites, intensive soil management appears essential. This note reports early results of tests of several soil management techniques for rejuvenating old fields for cottonwood production.

[1] The authors are Soil Scientists at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Mississippi, by the Southern Forest. Experiment Station, USDA Forest Service, in cooperation with the Mississippi Agricultural & Forestry Experiment Station and the Southern Hardwood Forest Research Group.

METHODS

The study area was an abandoned old field on Crown Zellerbach Corporation property in Sharkey County, Mississippi. It had been previously cropped, pastured, and used as an airstrip. Soil is a Commerce silty clay loam. Soil management techniques applied prior to planting included separate and combined treatments of

1. Cover cropping: Winter rye and vetch seeded (25 lbs./acre of each) on disked plots in September 1969. The cover crop was incorporated into the soil by disking in January 1971.
2. Deep plowing: Plowing to a 16-inch depth with a moldboard plow in September 1970.
3. Summer fallowing plus herbicide: Plots disked four times between June and August 1970. One lb. of active trifluralin per acre was applied in September 1970 and incorporated into the soil by disking.
4. Control: No treatment.

Treatments were replicated three times in a randomized complete-block design. Plots were 30 by 800 feet. Cottonwood cuttings were planted at 10- by 10-foot spacing in February 1971. All plots were disked in January 1971 to prepare for planting and were cultivated periodically during the first growing season.

In an exploratory trial 1 year prior to the main study, an adjacent area was deep-plowed with a disk panplow and a bullhead plow. Summer fallowing with and without deep plowing was also tested. Cottonwoods were planted as in the main study, and height and survival were observed 2 years after planting.

RESULTS AND DISCUSSIONS

Fallowing during the summer prior to planting and applying herbicide significantly (0.05 level) improved first-year survival and growth of planted cottonwood (table 1 and fig. 1). On fallowed plots, 85 percent of the cuttings survived, and heights averaged 9.7 feet after 1 year. On the unfallowed plots, survival was 67 percent, and trees averaged only 7.0 feet in height. Cover cropping and deep plowing, alone or in combination, improved neither growth nor survival. These treatments also failed to provide significant additional benefit when combined with fallowing-herbicide application.

Table 1.—*Relation of first-year height and survival of cottonwood to soil management treatments*

Treatment	Tree height [1]	Survival [2]
	Feet	*Percent*
No fallow or herbicide		
Control	6.0 b [3]	68 b
Cover crop	7.1 b	62 b
Deep plow	7.2 b	73 b
Cover crop + deep plow	7.7 b	66 b
Mean	7.0	67
Summer fallow and herbicide	9.4 a	84 a
+ Cover crop	9.6 a	86 a
+ Deep plow	9.8 a	85 a
+ Cover crop + deep plow	10.0 a	85 a
Mean	9.7	85

[1] Each value is the mean of three replications, about 160 measured trees.

[2] Each value is the mean of three replications, about 240 planting spots.

[3] Within columns, individual treatment means not followed by the same letter are significantly different at the 5-percent level according to a Duncan's test.

In the exploratory experiment, trees on summer-fallowed plots (to which no herbicide was applied) were significantly taller than trees on unfallowed plots (table 2 and fig. 2). Deep plowing in combination with summer fallowing failed to induce additional growth.

Figure 1.—*Cottonwood on plots that had been summer-fallowed and treated with herbicide (right) had 20-percent better survival and averaged 3 feet taller after 1 year than did trees on the control plots (left).*

Table 2.—*Relation of second-year height and survival of cottonwood to deep plowing and summer fallowing*

Treatment	Tree height [1]	Survival [2]
	Feet	*Percent*
No summer fallow		
Disk panplow	18.3 b [3]	80 a
Bullhead plow	17.7 b	67 b
Mean	18.0	74
Summer fallow	22.7 a	70 b
+ Disk panplow	22.7 a	78 a
+ Bullhead plow	22.3 a	65 b
Mean	22.6	71

[1] Each value is the mean of three replications, about 40 measured trees.

[2] Each value is the mean of three replications, about 60 planting spots.

[3] Within columns, individual treatment means not followed by the same letter are significantly different at the 5-percent level according to a Duncan's test.

The increases attributable to fallowing were of about the same magnitude in the two experiments, even though no herbicide was applied in the exploratory experiment. The lack of a pronounced herbicide effect may have been due to periodic cultivation of all plots throughout the growing season to control Johnson grass *(Sorghum halpense* (L.) Pers.). If the area had not been cultivated, the effects of herbicide might have been significant.

Why is fallowing of compacted old-field soils during the summer prior to planting beneficial? It probably temporarily improves soil structure and reduces competing vegetation, particularly Johnson grass. All fallowed plots on both study areas were relatively free of Johnson grass, the primary competitor to planted trees, during the 2 years after planting.

Summer fallowing is widely used in agriculture, especially in semiarid regions, for weed control and soil moisture conservation. Both benefits are also important for establishing hardwood plantations. The favorable results from summer fallowing reported here indicate that this technique may be useful in establishing hardwood plantations.

Figure 2.—*Two-year-old cottonwood on plots that had been summer-fallowed (left) were 5 feet taller than trees on unfallowed plots (right).*

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RAINFALL INFLUENCES FEMALE FLOWERING OF SLASH PINE

Eugene Shoulders [1]

SOUTHERN FOREST EXPERIMENT STATION

In a heavily thinned and cultivated plantation of slash pine, February through July rainfall in the year preceding flowering and interactions involving rainfall accounted for 23 percent of the total variation in female flowering of individual trees in a given year. Variation associated with rainfall was about half of that not associated with (1) inherent tendency of trees to flower, (2) rate of annual fertilization, and (3) flower production 2 years earlier. Annual rate of application of 15-25-10 analysis fertilizer and inherent tendency of trees to flower influenced the relationship between rainfall and flowering.

Additional keywords: Seed orchard, mineral nutrition, irrigation, fertilization, moisture relations, *Pinus elliottii*.

Both direct and indirect effects of moisture supply on female flowering of forest trees must be better understood if maximum benefit is to be realized from irrigation and fertilization of seed orchards. The research reported here explored relationships between spring and early summer rainfall in the year flower buds developed and female strobili production of individual slash pine *(Pinus elliottii* Engelm.) trees. Moreover, it attempted to ascertain how these relationships were influenced by annual rate of application of a 15-25-10 fertilizer and by inherent ability of the trees to flower. How rainfall and the other factors may have affected physiology of the trees and thereby influenced flowering is also discussed in the paper.

The relationships were investigated and described by correlation analyses and regression. The procedure for screening independent variables was such, however, that probability statements may not be made about the reliability of the regression equation. Thus, the solution is a first approximation and must be confirmed or refined by additional study.

MATERIALS AND METHODS

The relationships were developed from 7-year female flowering histories of 39 individual trees that were 22 years old when the study started and from rainfall data collected about ½ mile from the study area. The trees were permanent samples, selected at random, in a larger study of the effects of fertilization on flower and cone production *(27)*. Beginning in

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1958, they were fertilized each spring with nitrogen, phosphate, and potash at rates equivalent to 0, 250, 500, and 1,000 pounds per acre of 15-25-10. The plots were disked each June to a depth of about 4 inches with a heavy-duty offset farm disk.

The plantation initially contained about 115 square feet of basal area per acre in 319 stems. It was thinned to 50 square feet per acre during the winters of 1957-58 and 1962-63. Stocking averaged 98 trees per acre after the first and 67 trees per acre after the second thinning. Vigorous, well-formed dominants and codominants were retained. Trees that had produced cones previously were favored over individuals that had not.

Only the first thinning released the residual trees substantially; the second maintained the prescribed stand density by removing the smallest, least desirable trees.

Soil, Beauregard very fine sandy loam to silt loam, is inherently infertile by agronomic standards. Topography is level to slightly sloping and surface runoff is slow. Permeability is slow to moderately slow. Site index averages about 95 feet at age 50 for slash pine.

Female strobili were completely inventoried each spring from 1959 to 1965 by climbing the trees. Annual production of individual trees ranged from none to 441 and averaged 92 strobili. Unfertilized trees averaged 63 strobili each; heavily fertilized trees averaged 132. Maximum, minimum, and average amounts of rainfall for February through July in 1960 to 1964 are shown in table 1.

Table 1.—*Mean, minimum, and maximum rainfall in certain month, 1960-1964*

Month	Rainfall		
	Mean	Minimum	Maximum
	Inches		
February	3.84	1.43	6.80
March	3.78	.54	10.20
April	3.79	1.40	9.37
May	3.08	2.65	3.42
June	4.78	.68	10.74
July	3.61	2.18	5.46

Since the purpose of this investigation was to determine how rainfall directly or indirectly influenced the number of female flowers produced each year by individual trees, it was desirable to characterize the contribution to size of the current crop of other factors known to affect flowering—especially fertilizer rate *(27)*, cone or seed production in the year preceding flowering *(17, 30)*, and fruitfulness *(7,24,26,28,29)*. Flower production of individual trees in the years 1959 through 1963 was used as an index of cone or seed production in the years 1960 through 1964 (the years preceding the 1961 through 1965 flower crops). Average 7-year flower production per tree was chosen as an index of fruitfulness. Because the factors were interrelated, the entry of them into the regression was specified to follow the order of fertilizer rate, fruitfulness, and flowering 2 years earlier. The three factors collectively accounted for 53 percent ($R = 0.73$) of the variation in annual flower production of individual trees in the years 1961 through 1965. Moreover, annual flowering increased with rate of fertilization and improved inherent ability to flower and declined as size of the flower crop 2 years earlier became larger. These relationships were consistent with those reported in the literature cited above for individual factors. Therefore, fertilizer rate, average flowering, and flowering 2 years earlier were included in all subsequent analyses.

There were 195 sets of observations in a span of 5 years for the analyses. Only linear relationships were tested. Many combinations of variables were screened to determine the contribution of rainfall to flowering after the effects of fertilizer rate, average flowering, and flowering 2 years earlier had been removed. February through July rainfalls for the year preceding flowering, by individual months and by periods of 2, 3, 4, 5, and 6 consecutive months, were evaluated by Grosenbaugh's *(10)* system for combinational screening of multivariate regressions. In the screening, rainfall variables were grouped so that comparisons were made between all possible combinations which included once and only once in their independent variables all monthly rainfalls between two specific points in time. Two equations were chosen for additional testing. The first contained two rainfall variables: February + March + April rainfall and May + June rainfall. The second equation included rainfall for all 6 months distributed among three variables: February + March rainfall,

April rainfall, and May + June + July rainfall.

The second equation had the smallest relative mean squared residual of all solutions that satisfied the restrictions given. By the same standards, the first equation was the best regression with two rainfall variables.

Interactions between the selected independent variables were added to the two equations by a stepwise procedure if their individual *F* ratios exceeded 5.0 when they entered. The regression that included February through July rainfall among its independent variables was selected as the best empirical model because it had a larger coefficient of determination (R^2) and a smaller standard error of estimate than the other solution.

RESULTS

February through July rainfall in the year of flower bud formation accounted for 24 percent of the variation in annual female flowering of individual trees after effects of fertilizer rate, average flower production per tree, and flowering 2 years earlier were removed; it increased the multiple correlation coefficient for the regression to 0.80. Interactions between rainfall and other variables further increased the coefficient to 0.87. Thus, about half the variation not accounted for by fertilizer rate and tree characteristics was associated with rainfall and interactions involving rainfall.

Flowering response to rainfall varied by season of the rain, and to secure the best fit, separate regression coefficients were needed for February plus March rainfall, April rainfall, and May through July rainfall.

Response to February and March rainfall was always positive and was improved by fertilization or by a high inherent ability to flower (fig. 1). Response to April rainfall was positive or negative depending on levels of fertilization and flowering potential. It was positive for unfertilized trees that averaged 14 or more female flowers or for heavily fertilized trees that averaged 39 or more. The response was negative if trees averaged fewer than these numbers of flowers. Annual applications of fertilizer lowered the response to April rain if other factors remained equal. Response of current flowering to May, June, and July rainfall was always negative and became more negative as rate of fertilizer application or inherent ability to flower increased.

Figure 2 illustrates responses of representative low, medium, and high producing trees to varying amounts of fertilizer and rainfall. Heavily fertilized low producers and unfertilized high producers are not shown because

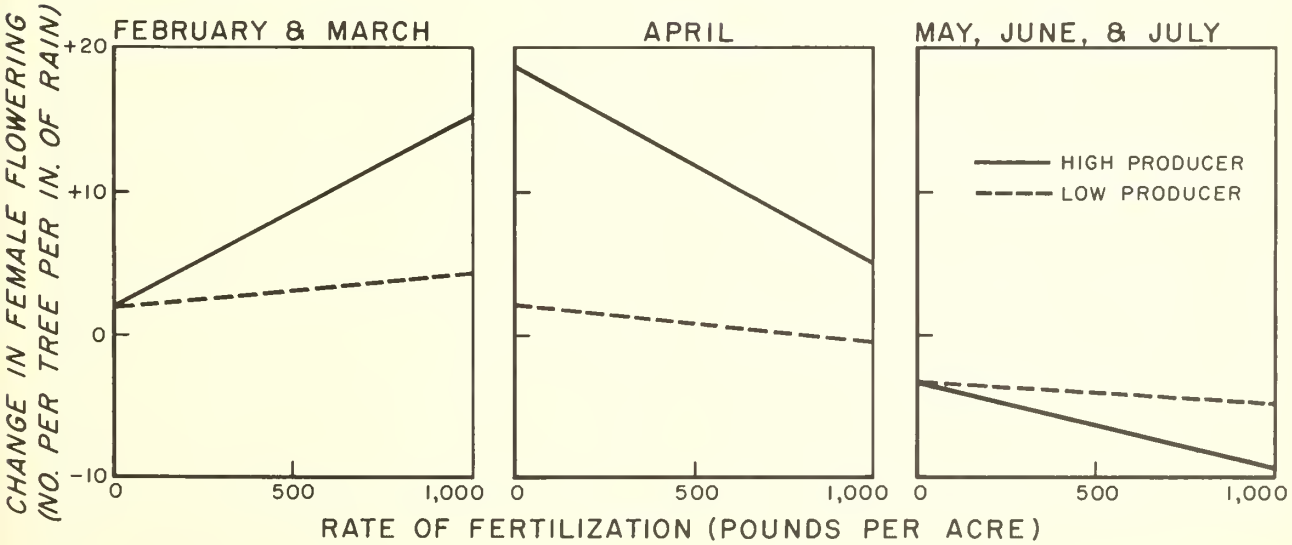

Figure 1.—*Effect of fertilizer rate and ability to flower on response to spring and early summer rainfall in the year flower buds formed. Responses in any time period assume no change in rainfall in other periods. Average flower yields were assumed to be 30 per tree for low and 150 per tree for high producers.*

such trees were poorly represented in the original data. Their scarcity resulted in part from including some response to fertilizers in computing potential productivity.

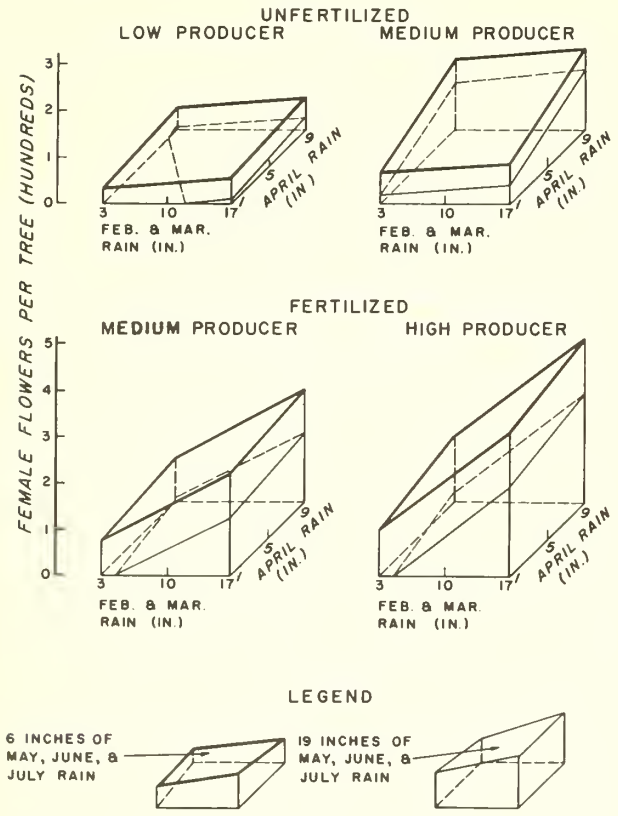

Figure 2.—*Estimated flowering of low, medium, and high producers at different rates of fertilization with 15-25-10 and amounts of rainfall in months preceding flower bud formation. Average flower yields were assumed to be 30 per tree for low, 95 for medium, and 150 for high producers. Production 2 years earlier was set at 35, 105, and 175, respectively.*

These representative solutions indicate negative current yields for certain situations. Negative solutions are probably due in part to linear analyses of relationships that are curvilinear. In any case, precision was sufficient to identify major trends in the relationships between current yield and rainfall alone or rainfall in combination with other factors.

Computed yields of all categories of trees increased as February through April rainfall increased. They declined with increasing May through July rainfall. Heavy fertilization reduced the response of medium producers to April rainfall and increased their response to February plus March rainfall. Thus, predicted yields were lower for heavily fertilized than for unfertilized medium producers that received small amounts of rain in February and March and large amounts in April. Similarly, fertilization depressed yields of medium producers that received small amounts of February through April and large amounts of May through July rain.

The effects of heavy fertilization and high inherent ability to flower were complementary. Trees having these advantages produced more flowers than any others unless February plus March rainfall was unusually low and either April rainfall or May through July rainfall was unusually high. Under these conditions, heavy annual fertilization reduced current yields.

When interactions between rainfall and other variables were omitted, the solution indicated that flowering increased with increasing April and February plus March rainfall, and declined with increasing May through July rainfall.

DISCUSSION

The complex relationships reported above are supported in part by other research. They are similar in many ways to those I found earlier between flowering of longleaf pine *(P. palustris* Mill.), rainfall, annual rate of fertilization, and inherent ability to flower *(26)*. But, there were two important differences: only April through July rainfall of the year preceding flowering was included in the longleaf solution; and abundant rainfall in all months was associated with maximum flowering of longleaf trees, whereas abundant May through July rainfall reduced flowering of slash pines. Whatever the reason for the differences, a forced fit of the slash data to the empirical model developed for longleaf pine supported the negative response of slash pine to high July rainfall and confirmed the desirability of including February and March rainfall in the solution.

Additional support that the slash pine model more precisely expresses response of slash flowering to moisture supply is provided by irrigation studies in seed orchards. Bengtson *(5)* found that yearlong irrigation at rates

which overcame current moisture deficits as estimated from Zahner's *(31)* work reduced female flowering of slash pine in a Florida plantation containing 24 clones of the species. In eastern Texas, Dewers and Moehring *(8)* found that April through September irrigation of a loblolly pine seed orchard on deep sand did not increase female flowering, but that 3 months of irrigation followed by 3 months of drought did. The soil moisture regime created by irrigation and drought was similar to the one suggested by the slash solution. Deep sands store only small amounts of available moisture, which is rapidly depleted in summer in eastern Texas. If it was at field capacity in early April, the Beauregard silt loam of the present study would contain enough available moisture *(19)* to satisfy Zahner's *(31)* estimated evapotranspirational needs of a fully stocked pine stand in Louisiana through May.

Investigations of the combined effects of moisture supply and fertilizer applications on female flowering have been inconclusive. Gregory [2] reported mixed response to annual complete fertilization and supplemental irrigation in two loblolly pine seed orchards in North Carolina. In one orchard, response to fertilizer was increased by supplemental irrigation during the growing season. Nitrogen fertilization increased female flowering on the irrigated slash pine clonal plantation mentioned earlier *(1,2)*.

The present study did not determine why flowering was influenced as it was by rainfall and fertilization, but other research has provided clues. Relatively high concentrations of carbohydrates are apparently necessary for flower-bud initiation *(14)*, which commences by August of the year preceding flowering *(9,22)*. Hepting *(11)* found that carbohydrate reserves in roots of shortleaf pine *(P. echinata* Mill.) were highest in early spring and lowest in autumn. They declined markedly in April, May, and early June, rose in July, then declined to their lowest levels. Reserves in stem wood and bark remained fairly stable. McKee and Sommers *(20)* reported similar spring highs and autumn lows in roots of slash pine seedlings. The spring decline reported by Hepting *(11)* coincides with the period of most active vegetative growth of southern pines *(3,4,9)*, whereas the late summer decline occurred while flower bud primordia were being produced *(9,22)*.

Abundant rainfall early in the year should promote vegetative growth, deplete food reserves, and increase photosynthetic capacity later in the year by increasing leaf, or needle, area. Application of a complete fertilizer should intensify and prolong vegetative growth and intensify the initial drain on stored foods. All these phenomena have been observed in conifers *(3,4,6,9,12,15,16,21,25)*, but no one has measured all of them concurrently under the particular conditions listed above.

Fertilization should also increase photosynthetic capacity of the trees by increasing leaf area and/or promoting synthesis of chlorophyll *(6,13)*. McKee and Sommers *(20)* observed that carbohydrate levels were higher in September in roots of slash pine seedlings fertilized about a year earlier with 300 pounds per acre of nitrogen than in roots of unfertilized seedlings. Although shoot growth declines markedly after the spring flushes *(9)*, continued abundant available moisture favors rapid cambial growth *(3,4,23)*, which would reduce the amount of stored and current photosynthate available for flower bud initiation. In competition for carbohydrates, preference is shown in many plants for rapidly growing young fruit and vegetative buds over flowers *(18)*. A moderate moisture stress after luxuriant spring growth might curtail further vegetative growth without seriously reducing photosynthesis and thereby favor accumulation of readily available carbohydrates at the time they are needed by developing flower buds. Hodges and Lorio *(12)* showed that imposed drought which drastically reduced soil moisture supply after about mid-May markedly reduced diameter growth of loblolly pine and caused accumulation of carbohydrates in the inner bark. Control trees did not replace carbohydrates expended in spring growth until about September.

Moisture stress earlier in the year should curtail or delay spring growth and reduce the amount of current photosynthate available during differentiation of flower buds.

[2] Gregory, J. D. The effects of fertilization and irrigation on flowering and seed production of two loblolly pine (Pinus taeda L.) seed orchards. 128 p. M. S. Thesis. N. C. State Univ. 1968.

LITERATURE CITED

1. Barnes, R. L., and Bengtson, G. W.
   1968. Effects of fertilization, irrigation, and cover cropping on flowering and on nitrogen and soluble sugar composition of slash pine. For. Sci. 14: 172-180.
2. Barnes, R. L., and Bengtson, G. W.
   1968. Some aspects of nitrogen nutrition and metabolism in relation to fertilizer responses in southern pines. *In* Forest fertilization—theory and practice, p. 58-63. TVA Nat. Fert. Develop. Center, Muscle Shoals, Ala.
3. Bassett, J. R.
   1964. Diameter growth of loblolly pine trees as affected by soil-moisture availability. USDA For. Serv. Res. Pap. SO-9, 7 p. South. For. Exp. Stn., New Orleans, La.
4. Bassett, J. R.
   1966. Seasonal diameter growth of loblolly pines. J. For. 64:674-676.
5. Bengtson, G. W.
   1969. Growth and flowering of clones of slash pine under intensive culture: early results. USDA For. Serv. Res. Pap. SE-46, 9 p. Southeast. For. Exp. Stn., Asheville, N. C.
6. Brix, H., and Ebell, L. F.
   1969. Effects of nitrogen fertilization on growth, leaf area, and photosynthesis rate in Douglas-fir. For. Sci. 15:189-196.
7. Croker, T. C., Jr.
   1964. Fruitfulness of longleaf trees more important than culture in cone yield. J. For. 62:822-823.
8. Dewers, R. S., and Moehring, D. M.
   1970. Effect of soil water stress on initiation of ovulate primordia in loblolly pine. For. Sci. 16:219-221.
9. Eggler, W. A.
   1961. Stem elongation and time of cone initiation in southern pines. For. Sci. 7:149-158.
10. Grosenbaugh, L. R.
    1967. REX—Fortran-4 system for combinatorial screening or conventional analysis of multivariate regressions. USDA For. Serv. Res. Pap. PSW-44, 47 p. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.
11. Hepting, G. H.
    1945. Reserve food storage in shortleaf pine in relation to little-leaf disease. Phytopathology 35:106-119.
12. Hodges, J. D., and Lorio, P. L., Jr.
    1969. Carbohydrate and nitrogen fractions of the inner bark of loblolly pines under moisture stress. Can. J. Bot. 47:1651-1657.
13. Kramer, P. J.
    1958. Photosynthesis of trees as affected by their environment. *In* K. V. Thimann (ed.) The physiology of forest trees, p. 157-186. N.Y.: Ronald Press Co.
14. Kramer, P. J., and Kozlowski, T. T.
    1960. Physiology of trees. 642 p. N. Y.: McGraw-Hill Book Co.
15. Krueger, K. W.
    1967. Nitrogen, phosphorus, and carbohydrate in expanding and year-old Douglas-fir shoots. For. Sci. 13:352-356.
16. Krueger, K. W., and Trappe, J. M.
    1967. Food reserves and seasonal growth of Douglas-fir seedlings. For. Sci. 13:192-202.
17. Lester, D. T.
    1967. Variation in cone production of red pine in relation to weather. Can. J. Bot. 45:1683-1691.
18. Loomis, W. E.
    1953. Growth correlations. *In* W. E. Loomis (ed.) Growth and differentiation in plants, p. 197-217. Ames, Iowa: Iowa State Coll. Press.
19. Lund, Z. F., Loftin, L. L., and Earle, S. L.
    1961. Supplement to physical characteristics of some representative Louisiana soils. USDA Agric. Res. Serv. ARS 41-33-1, 43 p.
20. McKee, W. H., Jr., and Sommers, R. A.
    1971. Slash pines respond equally to nitrogen applications in fall and

spring. USDA For. Serv. Res. Note SO-128, 4 p. South. For. Exp. Stn., New Orleans, La.

21. Maki, T. E.
    1960. Some effects of fertilizers on loblolly pine. Int. Congr. Soil Sci. 4(47):363-375. Madison, Wis.

22. Mergen, F., and Koerting, L. E.
    1957. Initiation and development of flower primordia in slash pine. For. Sci. 3:145-155.

23. Moehring, D. M., and Ralston, C. W.
    1967. Diameter growth of loblolly pine related to available soil moisture and rate of soil moisture loss. Soil Sci. Soc. Am. Proc. 31:560-562.

24. Pomeroy, K. B.
    1949. Loblolly pine seed trees: selection, fruitfulness, and mortality. USDA For. Serv. Southeast. For. Exp. Stn., Stn. Pap. 5, 17 p.

25. Rangnekar, P. V., Forward, D. F., and Nolan, N. J.
    1969. Foliar nutrition and wood growth in red pine: the distribution of radiocarbon photoassimilated by individual branches of young trees. Can. J. Bot. 47:1701-1711.

26. Shoulders, E.
    1967. Fertilizer application, inherent fruitfulness, and rainfall affect flowering of longleaf pine. For. Sci. 13:376-383.

27. Shoulders, E.
    1968. Fertilization increases longleaf and slash pine flower and cone crops in Louisiana. J. For. 66: 193-197.

28. Varnell, R. J., Squillace, A. E., and Bengtson, G. W.
    1967. Variation and heritability of fruitfulness in slash pine. Silvae Genet. 16:125-128.

29. Wenger, K. F.
    1954. The stimulation of loblolly pine seed trees by preharvest release. J. For. 52:115-118.

30. Wenger, K. F.
    1957. Annual variation in the seed crops of loblolly pine. J. For. 55: 567-569.

31. Zahner, R.
    1956. Evaluating summer water deficiencies. USDA For. Serv. South. For. Exp. Stn. Occas. Pap. 150, 18 p.

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ELECTROPHORESIS PATTERNS OF NEEDLE ENZYMES IN LONGLEAF AND SONDEREGGER PINES

J. M. Hamaker and E. B. Snyder

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Screening of 53 enzymes revealed 19 that were active and nine of these that were potentially useful for genetic studies of longleaf pine and its hybrids.

Additional keywords: Isozymes, introgression, *Pinus taeda*, *Pinus palustris*.

Isozymes, multiple variants of enzymes, can be separated by electrophoresis, and the patterns of their occurrence may identify species hybrids or indicate gene action in individual trees and their intraspecific progeny. In research reported here, 53 enzymes were screened by polyacrylamide disc gel electrophoresis to determine those likely to be useful in our pine genetics research.

MATERIALS AND METHODS

Samples were chosen to aid in distinguishing possible traces of introgressed loblolly pine (*Pinus taeda* L.) in rare blackseeded trees of longleaf pine (*P. palustris* Mill.). Tests for each enzyme were performed on the same 12 trees. One tree was from each of 12 families: Longleaf × wind (3 families), longleaf × Sonderegger (*P. palustris* × *P. taeda*) (3 families with the same longleaf parents as in first group), Sonderegger × Sonderegger (1), loblolly × Sonderegger (1), and putative Sonderegger × wind (4).

Mature needles were collected from the trees and immediately frozen. Five grams of finely chopped needles per tree were added to 150 ml. of cold acetone and ground in a blender. After coarse fibers were screened, the suspension was centrifuged. The recovered pellet was washed, dried, screened to a fine powder, and stored at —15° C. until the proteins were extracted. The protein extraction solution contained 15 percent urea, 0.5 percent $K_2S_2O_5$, 1 percent ascorbic acid, 0.1 percent dithiothreitol, and 0.4 percent trition X-100 in an aqueous solution adjusted to pH 8.5 with tris (hydroxymethyl) aminomethane. The powder was aliquoted into three to five 30-mg. lots, each sufficient for the assay of four or five enzymes (12 to 25 total). A 30-mg. lot of powder was extracted for 2 hours in 0.4 ml. of the extracting solution and the brei was centrifuged at 17,000 r.p.m. for 15 minutes.

Gels and electrolytic buffers for the 12-disc chamber were prepared according to Hare (*8*). Current at 30 milliamperes was applied to the discs until the marker dye traversed the length of the gel. Then 10 μl of the supernatant were layered on each gel and the current was applied

again for 30-45 minutes, or until the second dye front reached the end of the gel. The gels were then removed and appropriately stained. Each sample was analyzed at least twice per enzyme.

Methods for only a few of the hundreds of enzymes that may be present in leaf tissue are listed in table 1. Procedures for others are not published or are too time consuming or expensive for our purpose. Readers can determine our modifications by noting which enzymes have been modified and then comparing our formulations with those from original references. It will often be necessary to consult these references before carrying out analyses.

RESULTS AND DISCUSSION

Of the 53 enzymes screened 19 showed activity, and nine of these appear to be potentially useful in pine genetics research: peroxidase, esterase, catalase, acid phosphatase, ascorbic acid oxidase, cytochrome oxidase, phenoloxidase, polyphenoloxidase, and malate dehydrogenase. Numbers of visible isozyme bands formed during electrophoresis are shown in the final column of table 1. A zero indicates that the enzyme either was not present in needle tissue or was not detected by the method described.

Peroxidase bands may be helpful in distinguishing longleaf pine from hybrids of longleaf and loblolly pine (fig. 1). Since our main purpose is to evaluate technique rather than genetic results, patterns of only some of the 12 trees are shown. In the figures, the origin of the material is designated "O"; the fastest band is farthest from this point. The fast and slow bands of peroxidase in Sonderegger tree 2-7 are of particular interest. These bands are lost when this tree is crossed with longleaf 12-1. Parent 12-1 may be carrying a dominant inhibitor and these bands may be pleiotropic. The second slowest band should help distinguish pure longleaf from hybrids, since it is absent in hybrids.

The number of esterase isozymes present varied considerably. These isozymes provided no criterion for assigning trees to specific taxa, but they may be useful for studying tree-to-tree variation (fig. 2).

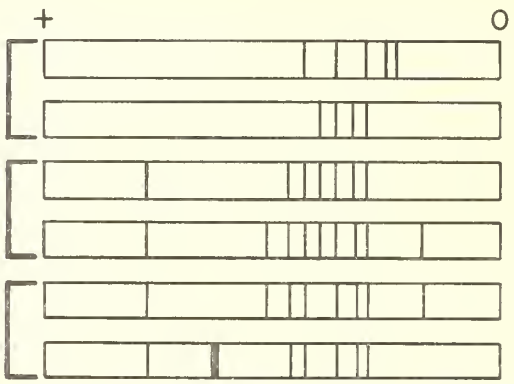

Figure 2.—*Esterase isozyme bands in backcrosses to three different longleaf parents. Each of the three gel pairs bracketed at left include the Sonderegger backcross to longleaf (top) and the corresponding longleaf × wind (bottom). Note variation among pairs in number of bands.*

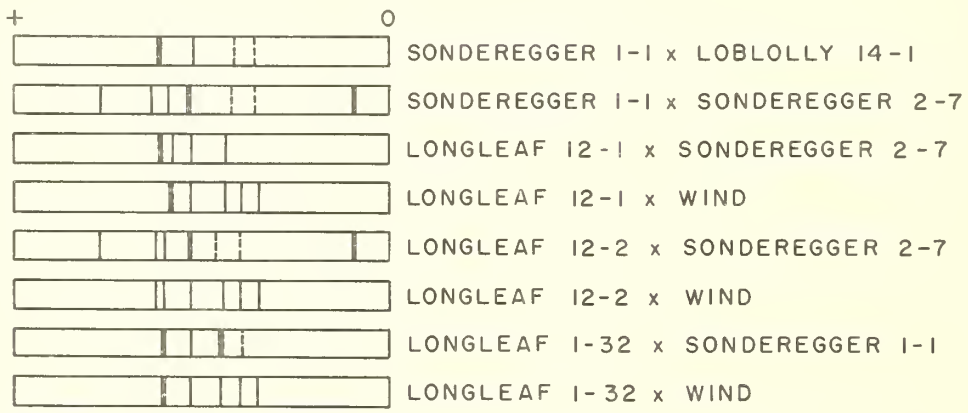

Figure 1.—*Schematic diagrams (zymograms) of peroxidase isozyme bands. Species composition of the plant material processed on each gel is indicated at the right. O = origin; + = anode. Note the unique fast band and the unique slow band of Sonderegger 2-7 and that the second slowest band is present only for longleaf × wind.*

Table 1.—*Summary of 53 enzymes*

Enzyme and reference	Buffer			Substrate and stain	Amount in 50 ml. buffer	Bands
	Type	pH	Concentration			
			Mole/liter		*Mg. or ml.*	*Number*
Hydrolases						
Acid phosphatase *(23)*	Acetate	5.0	0.2	K α-naphthyl acid phosphate	60	4-9
				Fast Garnet GBC	10	
Alkaline phosphatase *(3,13)*	Tris-HC1	8.5	.05	K α-naphthyl phosphate	50	3
				PVP	250	
				$MgC1_2$	20	
				Fast blue RR	44	
Amylase *(8)* [1]	Acetate	4.4	.2	IKI solution	50	0
				Iodine, 0.004%		
				KI, 1.5%		
				(0.3% starch in gel)		
Esterase *(2)*	Phosphate	6.2	.1	α-naphthyl acetate, 1%		5-10
				in 70% ETOH	1	
				Fast blue RR	50	
β-Galactosidase *(17)*	Prosphate-citrate	5.0	.01	6-Bromo-2-naphthyl-β-D		0
				galactopyranoside	15	
				Fast blue B, or	100	
				Fast violet B	100	
β-Glucuronidase *(13)*	Acetate	5.0	.2	8-hydroxyquinoline		0-1
				glucuronide	26	
				Fast blue RR	50	
Leucine aminopeptidase *(3, 20)*	Tris-malate	6.2	.2	L-leucyl-β-naphthylamide HC1	20	0
				Black K salt	25	
				(0.5% starch in gel)		
Lipase *(16)*	Phosphate	6.2	.1	α-naphthyl laurate 1%	1	0
				Fast blue RR	50	
Ribonuclease *(20)* [1]	Acetate	5.0	.05	RNA (Torula yeast)	125	0
				Acid phosphatase	5	
				Black K salt	50	
Urease *(4)*	Citrate	6.0	.05	Urea	312	0
				Clelands reagent	14	
				NBT	25	
Isomerases						
Phosphoglucose isomerase *(14)*	Phosphate	7.4	.05	Fructose-6-phosphate	44	[2] 1
				magnesium sulfate	176	
				NADP	44	
				NBT	44	
Lyases						
Aldolase *(19)*	Phosphate	8.0	.05	2-hydroxy-3-naphthoic		1
				acid hydrazide	30	
				Na_4 fructose 1,6-		
				diphosphate·4.5 H_2O	273	
				Fast violet B	100	
Oxidoreductases						
Alanine dehydrogenase *(20)* [1]	Phosphate or	7.0	.1	L-alanine	50	0
				NAD	25	
	Tris-HC1	7.5	.05	PMS	1	
				NBT	15	
Alcohol dehydrogenase *(8)* [1]	Tris-HC1	8.0	.05	ETOH	2.5	[2] 2-5
				NAD	3.5	
				PMS	1	
				NBT	10	
Aldehyde dehydrogenase *(20)*	Tris-HC1	7.5	.05	Acetaldehyde, 0.2M	.15	[2] 1
				NAD	35	
				PMS	1	
				NBT	15	

[1] Unmodified methods.
[2] These are thought to be bands of NBT reductase and are nonspecific for the substrate.

Table 1.—*Summary of 53 enzymes* (Continued)

Enzyme and reference	Buffer			Substrate and stain	Amount in 50 ml. buffer	Bands
	Type	pH	Concentration			
			Mole/liter		*Mg. or ml.*	*Number*
L-Amino acid oxidase *(10)* [1]	Tris-HCl	7.5	.14	L-leucine	138	[2] 2-3
				PMS	1	
				2,3,5-triphenyl tetrazolium chloride	18	
Ascorbic acid oxidase *(8)*	Citrate-phosphate	5.0	.15	(A) Ascorbic acid	15	5-6
				(B) 2,6-dichloroindophenol	25	
				(C) Ascorbic acid	10	
Catalase *(2)*	None			(A) H_2O_2, 0.1 percent		5-7
				(B) KI	250	
				Acetic acid	.25	
				(C) NaOH, 0.1M		
				(D) Repeat (B)		
				(0.5 percent starch in gel)		
Choline dehydrogenase *(21)*	Tris-HCl	7.5	.05	Choline chloride	350	[2] 3
				$MgSO_4$	50	
				NAD	35	
				PMS	1	
				NBT	15	
Cytochrome oxidase *(8)* [1]	Phosphate	7.2	.1	α-naphthol	35	6-8
				N,N dimethylphenylenediamine	35	
				Sodium azide	35	
Dihydro-L-orotic acid dehydrogenase *(22)*	Tris-HCl	7.5	.05	Dihydro-L-orotic acid	480	0
				NAD	30	
				PMS	1	
				NBT	15	
Formazan oxidase (Tetrazolium oxidase) *(1, 9)*	Tris-HCl	7.5	.05	EDTA	75	9-10
				NBT	15	
				PMS	1	
Galactose dehydrogenase *(19)*	Tris-HCl	7.5	.05	D+galactose	450	[2] 3-5
				$MgSO_4$	50	
				NAD	35	
				PMS	1	
				NBT	15	
Galactose-6-phosphate dehydrogenase *(20)*	Tris-HCl	7.5	.05	D-galactose-6-phosphate	130	1
				NADP	20	
				PMS	1	
				NBT	25	
Glucose dehydrogenase *(20)*	Tris-HCl	7.5	.05	Glucose	495	[2] 2-4
				NAD	35	
				PMS	1	
				NBT	15	
Glucose-6-phosphate dehydrogenase *(8)* [1]	Tris-HCl	7.5	.05	D-glucose-6-phosphate·2Na	150	[2] 3-5
				$MgSO_4$	50	
				PMS	1	
				NBT	15	
				NADP		
Glutamate dehydrogenase *(20)* [1]	Phosphate	7.0	.1	Na glutamate	845	1
				NAD	30	
				NBT	15	
				PMS	1	
Glyceraldehyde-3-phosphate dehydrogenase *(20)* [1]	Tris-HCl	7.1	.2	Na_4 fructose 1,6-diphosphate·6 H_2O	272	0
				Aldolase	.3	
				NAD	25	
				PMS	1	
				NBT	15	
Hexose-6-phosphate dehydrogenase *(20)*	Tris-HCl	6.8	.1	Galactose phosphate	27	0
				NADP	25	
				PMS	1	
				NBT	15	

Table 1.—*Summary of 53 enzymes* (Continued)

Enzyme and reference	Buffer			Substrate and stain	Amount in 50 ml. buffer	Bands
	Type	pH	Concentration			
			Mole/liter		*Mg. or ml.*	*Number*
α- and β-Hydroxybutyric dehydrogenase *(13)*	Tris-HCl	7.5	.05	α-Hydroxybutyric acid or	100	0
				β-Hydroxybutyric acid	100	
				Hydrazine sulfate	5	
				PMS	1	
				TNBT	20	
Isocitrate dehydrogenase *(11, 20)*	Tris-HCl	7.5	.05	Na_3 isocitrate	64	[2] 3
				$MgSO_4$	50	
				NADP	16	
				PMS	1	
				NBT	15	
α-Ketoglu-terate dehydrogenase *(11)*	Tris-HCl	7.5	.05	α-Ketoglutaric acid	292	0
				$MgSO_4$	50	
				NAD	35	
				NBT	15	
				PMS	1	
Limonene reductase *(15)*	Tris-HCl	8.5	.1	NADH	25	0
				L-limonene 5 percent or	.1	
				Limonene dioxide 5 percent	.1	
				NBT	15	
Malate dehydrogenase *(8)* [1]	Tris-HCl	7.5	.05	L-Malic acid	200	3-5
				NAD	35	
				PMS	1	
				NBT	15	
Monoamine oxidase *(6)*	Phosphate	7.2	.1	Tryptamine HCl	60	[2] 2-3
				NBT	30	
Nicotinamide adenine dinucleotide dehydrogenase *(22)*	Tris-HCl	8.5	.05	NADH (β-Diphosphopyridine nucleotide, reduced form)	25	2
				NBT	20	
Nicotinamide adenine dinucleotide phosphate dehydrogenase *(22)*	Tris-HCl	8.2	.1	NADPH (Triphosphopyridine nucleotide, reduced form)	25	2
				NBT	20	
Nitrate reductase *(12)*	Phosphate	7.5	.01	(A) Buffer	23.5	0
				KNO_3, .1M	3.1	
				N-1-naphthylethylene-diamine 2HCl, .02 percent	7.8	
				Sulfanilamide, .5 percent	15.6	
				(B) HCl, .1N	50	
"Nothing" dehydrogenase (NBT reductase) *(18)*	Tris-HCl	7.5	.05	NAD or	35	2
				NADP	24	
				NBT	15	
				PMS	1	
Peroxidase *(8)* [1]	Acetate	5.0	.2	EDTA	250	4-7
				Benzidine 2HCl	50	
				H_2O_2, 3 percent	.25	
Phenoloxidase *(8)* [1]	Phosphate	7.2	.1	α-naphthol	35	4-7
				N,N-dimethylphenylenediamine	35	
				Thiourea	35	
6-Phospho-gluconate dehydrogenase *(11, 20)*	Tris-HCl	7.5	.05	Na_3 6-phosphogluconic acid	170	[2] 2
				NADP	20	
				$MgSO_4$	50	
				PMS	1	
				NBT	15	
Polyphenol-oxidase *(8)* [1]	Phosphate	7.2	.1	Catechol	35	4-8
				N,N-dimethylphenylenediamine	35	
				Thiourea	35	
Sorbitol dehydrogenase *(20)*	Tris-HCl	7.5	.05	Sorbitol	182	0
				NAD	30	
				PMS	1	
				NBT	15	

Table 1.—*Summary of 53 enzymes* (Continued)

Enzyme and reference	Buffer			Substrate and stain	Amount in 50 ml. buffer	Bands
	Type	pH	Concentration			
			Mole/liter		*Mg. or ml.*	*Number*
Tartrate dehydrogenase *(5)*	Tris-HCl	7.5	.05	D-Tartaric acid	376	0
				$MgSO_4$	50	
				NAD	30	
				PMS	1	
				NBT	15	
Xanthine dehydrogenase *(20)*	Tris-HCl	7.5	.05	Hypoxanthine	408	0
				KOH	561	
				NAD	30	
				PMS	1	
				NBT	15	
Transferases						
Arylsulfatase *(24)*	Acetate	5.0	.1	$Na_2P_2O_7 \cdot 10H_2O$	12	0
				NaCl, 10 percent Nitrocatechol sulfate	16	
Glutamic-oxalacetic transaminase *(3, 20 [1])*	Phosphate	7.0	.1	L-aspartic acid	266	0
				α-ketoglutaric acid	36	
				Pyridoxal phosphate	25	
				Fast violet B	100	
Hexokinase *(20)*	Tris-HCl	7.5	.05	Glucose	45	0
				ATP	13	
				NADP	13	
				Glucose-6-phosphate dehydrogenase	.125	
				PMS	1	
				NBT	15	
Lipoxidase *(7)*	Tris-HCl	8.3	.05	Linoleic acid	28	0
				Potassium iodide (1 percent starch in gel)	250	
Phosphoglucomutase *(20)*	Tris-HCl	7.5	.05	Na_2 glucose-1-phosphate	288	[2] 1-2
				NADP	5	
				PMS	1	
				Glucose-6-phosphate dehydrogenase	.018	
				NBT	15	
Phosphorylase *(25)*	Tris-HCl	7.5	.1	(A) Glucose-1-phosphate	250	0
				$MgCl_2$	.5	
				(B) KI, 0.5 percent acetic acid	.1	
				H_2O_2	.2	
				(1 percent glycogen in gel)		
Sucrose phosphorylase *(5)*	Phosphate	6.9	.003	Sucrose	3425	1
				2,3,5-Triphenyl tetrazolium chloride	50	

The method of staining for catalase bands included having starch in the gel, bleaching, and restaining with I_2 as listed in table 1. Four of the eight zymogram patterns found among the 12 trees are shown in figure 3. These patterns do not distinguish among species hybrids.

There were as many or more isozymes of acid phosphatase in the putative hybrid but fewer in the known hybrids than in pure longleaf (fig. 4). A larger sample would be desirable to resolve this apparent confusion.

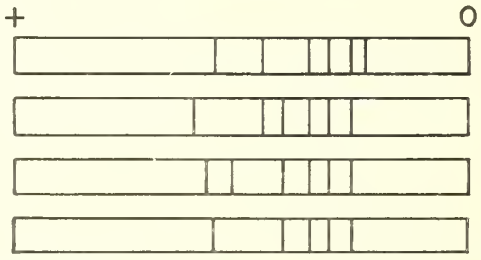

Figure 3.—*Catalase isozyme bands of four longleaf-like putative Sonderegger pines. Such tree-to-tree variation in band number and location was typical.*

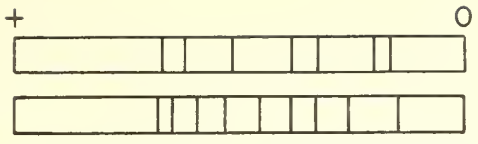

Figure 4.—*Zymograms of acid phosphatase. The longleaf (top) had fewer bands than the Sonderegger (bottom).*

Bands of ascorbic acid oxidase diffused rapidly, but they may have potential for distinguishing among hybrids. The second slowest band was present only in our longleaf sample (arrow in fig. 5), and its absence in hybrids should be useful for detecting hybridity.

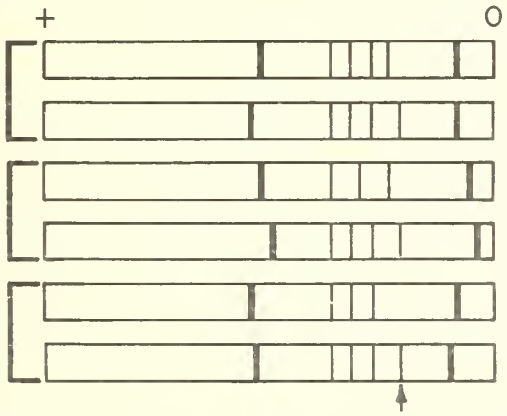

Figure 5.—*Zymograms of ascorbic acid oxidase. The slow band (arrow) was present in longleaf (bottom members of pairs) but not Sonderegger pine (top members).*

When staining for both cytochrome oxidase and phenoloxidase, α-naphthol is required. Sodium azide was added as an inhibitor of phenoloxidase. Slight differences were found among individuals but none among taxa (fig. 6). Isozyme patterns were similar for most trees when stained for phenoloxidase, but a few differed. The same is true for polyphenoloxidase and malate dehydrogenase. These enzymes could prove useful.

Figure 6.—*Typical isozyme pattern for cytochrome oxidase.*

With the rapid, inexpensive extraction and staining techniques which are practical in our laboratory, most enzymes shown in table 1 had little potential for pine genetics research. Substrates were not specific for 12 enzymes that required tetrazolium dyes for staining. Ten enzymes had one or more bands but were monomorphic, while 22 enzymes showed no bands.

Thus, of the 53 enzymes screened, peroxidase, ascorbic acid oxidase, and acid phosphatase appear useful for distinguishing pure longleaf from longleaf-like hybrids as well as for studying intraspecific tree-to-tree variation. For the latter purpose, esterase, cytochrome oxidase, and catalase also appear good, and polyphenoloxidase, phenoloxidase, and malate dehydrogenase have potential.

LITERATURE CITED

1. Baur, E. W., and Schorr, R. T.
   1969. Genetic polymorphism of tetrazolium oxidase in dogs. Science 166: 1524-1525.
2. Brewbaker, J. L., Upadhya, M. D., Mäkinen, Y., and MacDonald, T.
   1968. Isoenzyme polymorphism in flowering plants. III. Gel electrophoretic methods and applications. Physiol. Plant. 21: 930-940.
3. Brewer, G. J.
   1970. An introduction to isozyme techniques. 186 p. N. Y.: Academic Press.
4. Fishbein, W. N., Spears, C. L., and Scurzi, W.
   1969. Spectrum of urease isozymes: genetic, polymeric and conformeric. Nature 223: 191-193.
5. Gabriel, O.
   1971. Locating enzymes on gels. Methods Enzymol. 22: 578-604.
6. Glenner, G. G., Burtner, H. J., and Brown, G. W., Jr.
   1957. The histochemical demonstration of monoamine oxidase activity by tetrazolium salts. J. Histochem. Cytochem. 5: 591-600.
7. Guss, P. L., Richardson, T., and Stahmann, M. A.
   1967. The oxidation-reduction enzymes of wheat. III. Isoenzymes of lipoxidase in wheat fractions and soybean. Cereal Chem. 44: 607-610.

8. Hare, R. C.
1970. Physiology and biochemistry of pine resistance to the fusiform rust fungus, Cronartium fusiforme. 155 p. Ph.D. Thesis, Univ. of Fla.

9. Hare, R. C.
1973. Reducing interference by "Tetrazolium oxidase" and "Nothing dehydrogenase" when staining for dehydrogenase isozymes in polyacrylamide gels. Isozyme Bull. 6: 8-9. [Cornell Univ.]

10. Hayes, M. B., and Wellner, D.
1969. Microheterogeneity of L-amino acid oxidase. Separation of multiple components by polyacrylamide gel electrofocusing. J. Biol. Chem. 244: 6636-6644.

11. Honold, G. R., Farkas, G. L., and Stahmann, M. A.
1966. The oxidation-reduction enzymes of wheat. I. A qualitative investigation of the dehydrogenases. Cereal Chem. 43: 517-529.

12. Ingle, J.
1968. Nucleic acid and protein sythesis associated with the induction of nitrate reductase activity in radish cotyledons. Biochem. J. 108: 715-724.

13. Lawrence, S. H.
1964. The zymogram in clinical medicine. 124 p. Springfield, Ill.: Charles C. Thomas.

14. Orchardson, R., and McGadey, J.
1970. The histochemical demonstration of phosphoglucose isomerase. Histochemie 22(2): 136-139.

15. Potty, V. H., and Bruemmer, J. H.
1970. Limonene reductase system in the orange. Phytochemistry 9: 2319-2321.

16. Rudolph, K., and Stahmann, M. A.
1966. Multiple hydrolases in bean leaves *(Phaseolus vulgaris* L.) and the effect of the halo blight disease caused by *Pseudomonas phaseolicola* (Burkh.) Dowson. Plant. Physiol. 41: 389-394.

17. Scogin, R.
1969. Isoenzyme polymorphism in natural populations of the genus *Baptisia* (Leguminosae). Phytochemistry 8: 1733-1737.

18. Shaw, C. R., and Koen, A. L.
1965. On the identity of "nothing dehydrogenase." J. Histochem. Cytochem. 13: 431-433.

19. Shaw, C. R., and Koen, A. L.
1968. Starch gel zone electrophoresis of enzymes. *In:* Chromatographic and electrophoretic techniques 2: 325-364. 2nd. ed. Ivor Smith (ed.) N. Y.: Interscience Publishers.

20. Shaw, C. R., and Prasad, R.
1970. Starch gel electrophoresis of enzymes—a compilation of recipes. Biochem. Genet. 4: 297-320.

21. Sokolova, V. E., and Zviagintseva, Y. V.
1968. Method for determination of choline dehydrogenase activity in tissues of sugar beet root (as one of resistance factors to injury by phytophatogenes). Prikl. Biokhim. Mikrobiol. 4(1): 45-50 [Eng. Summary]

22. Wang, C-S., and Raper, J. R.
1970. Isozyme patterns and sexual morphogenesis in *Schizophyllum.* Nat. Acad. Sci. Proc. 66: 882-889.

23. Wennstrom, J. I., and Garber, E. D.
1965. The genus Collinsia. XXVII. Separation of esterases and acid phosphatases in extracts from twelve species and one interspecific hybrid by starch-gel zone electrophoresis. Bot. Gaz. 126: 223-225.

24. Werner, M., Maruhn, D., and Atoba, M.
1969. Use of gel filtration in the assay of urinary enzymes. J. Chromatogr. 40: 254-263.

25. Zweig, G., and Whitaker, J. R.
1967. Paper chromatography and electrophoresis. Vol. I. Electrophoresis in stabilizing media. 420 p. N. Y.: Academic Press.

SOUTHERN FOREST EXPERIMENT STATION

1973

U.S. FOREST SERVICE RESEARCH NOTE

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PRECOMMERCIAL THINNING INCREASES DIAMETER AND HEIGHT GROWTH OF SLASH PINE

Richard E. Lohrey [1]

SOUTHERN FOREST EXPERIMENT STATION

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Precommercial thinnings in a 3-year-old slash pine stand with about 5,000 stems per acre increased diameter growth of trees in all crown classes and increased height growth of dominants and codominants. For maximum growth, residual densities of 750 trees per acre or less were needed. At residual stocking levels of 1,400 and 2,800 trees per acre, strip and selective thinnings were equally effective.

Additional keywords: *Pinus elliottii* var. *elliottii,* thinning methods, thinning effects, strip thinning, cleaning.

Though precommercial thinning has been tried sporadically for many years, little is known about responses of the residual stand. Then, too, many trials have been installed in stands about 10 years old, where costs of thinning are high. This Note reports early results from a study in which a range of densities was established by thinning in 3-year-old direct-seeded slash pines *(Pinus elliottii* Engelm. var. *elliottii).*

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METHODS

The study area is near Alexandria, La. The soils are Bowie and Beauregard silt loams with a sandy loam surface about 6 inches deep and a sandy clay loam subsoil. These heavy, poorly drained soils are prevalent in western and central Louisiana. Since topography is nearly flat, surface drainage is also slow. Site index is estimated as 85 to 90 feet at 50 years.

The area was burned and single-disked in February 1959. A month later it was sown with 2 pounds of seed per acre to obtain a dense stand. Initial establishment and survival were good. At age 3 years, stocking on treatment plots, established in the denser portion of the stand, averaged 5,600 trees per acre. All trees were less than 4½ feet tall.

Twelve thinning treatments were tested. They included an unthinned check, five intensities of selective thinning, four strip thinnings, and two combinations of selective and strip thinnings. All were initiated when pines were 3 years old. Tall, healthy, well-spaced trees were favored in the selective thinnings, where residual densities ranged from 500 to

4,200 trees per acre. One strip thinning removed all trees on strips 6.6 feet wide and left unthinned swaths of equal width. Another, called the checkerboard treatment, consisted of 6.6-foot strip thinnings made perpendicular to each other, so that the residual stand was in clumps 6.6 feet square. The third strip thinning removed all trees on strips 9.9 feet wide and left unthinned swaths 3.3 feet wide. The two combined treatments consisted of a 6.6-foot strip thinning followed by selective thinnings to 1,400 trees per acre. In one treatment the selective thinning was made immediately, and in the other it was deferred for 2 years.

Unwanted trees were uprooted by hand in all treatments, except that one strip thinning was made with a 1,400-pound offset disk. The object was to determine if disking would kill unwanted trees, but so many pines survived that some disked strips were almost indistinguishable from undisked portions.

Plots are 0.1 acre in area with 0.5-chain isolation strips. Each treatment is replicated three times in a completely randomized design. Plots were inventoried before and after thinning at age 3 and reinventoried at ages 8 and 12 years. At each inventory, all trees were counted and total height was measured on sample trees. Diameter at breast height was measured on all trees at ages 8 and 12 years, and volumes were computed at age 12.

RESULTS

Mean total height of all trees averaged 2.2 feet after the thinnings at age 3 years. The tallest trees were in plots thinned selectively to 750 trees per acre. Differences in height among the other treatments were small (table 1).

At age 8 years, height of 25 well-spaced dominants and codominants per plot averaged 17.2 feet. By age 12, height had increased to 30.7 feet. These values are averages for all plots; differences among treatment means were not significant (0.05 level) at either age 8 or 12.

Periodic height growth of dominant and codominant trees was inversely related to number of trees per acre after thinning. A linear regression indicated that there was a 2-foot difference in height growth between heavily thinned and unthinned plots during the last 4 years. The equation for height growth (H) in the period from 8 to 12 years is:

Table 1.—*Trees per acre and mean total height by treatment and age*

Treatment	Trees/acre age 3	Total height			Height growth, 8 to 12 years
		Age 3 [1]	Age 8 [2]	Age 12 [2]	
	Number	*Feet*			
Unthinned check	5,090	2.0	17.9	30.4	12.5
4,200 selective	4,200	2.2	17.5	30.1	12.6
2,800 selective	2,800	2.2	16.9	30.4	13.5
1,400 selective	1,400	2.4	17.7	31.7	14.0
750 selective	750	3.0	18.8	32.9	14.1
500 selective	500	2.3	16.6	30.8	14.2
6.6-foot strip cut, 6.6-foot strip left	2,987	2.1	17.5	30.9	13.4
6.6-foot strip plus selective	1,400	2.2	16.8	30.4	13.6
6.6-foot strip plus deferred selective	[3] 2,413	1.8	16.5	31.3	14.8
6.6-foot strip, mechanical	3,033	2.1	16.8	29.2	12.4
Checkerboard	1,300	2.1	17.0	30.3	13.3
9.9-foot strip cut, 3.3-foot strip left	1,250	2.0	16.6	30.3	13.7

[1] Height of all trees.

[2] Height of dominants and codominants.

[3] Thinned to 1,400 trees per acre at age 5 years.

$$H = 14.4 - 0.000414 \text{ (trees per acre)}$$
$$r^2 = 0.42,\ Sy{\cdot}x = 0.70 \quad (1)$$

Mean diameters (diameter of the tree of mean basal area on each plot) at 12 years were inversely related to number of trees per acre after thinning at age 3 (T) and directly related to height (Ht). These relationships held for mean diameters of all trees, for dominants and codominants, and for the 100 largest trees per acre. Differences in mean diameters between selective and strip thinnings were not statistically significant at residual densities of either 1,400 or 2,800 trees per acre.

Data from all treatments were combined to compute regression equations that predict mean diameters at age 12 years for stands of various densities. The equations were:

$$\text{D.b.h. (all trees)} = 0.1833 - 0.0001445\ T + 935.0/T + 0.1027Ht$$
$$R^2 = 0.95,\ Sy{\cdot}x = 0.18 \quad (2)$$

$$\text{D.b.h. (dominants and codominants)} = 1.139 - 0.00006962\ T + 463.2/T + 0.1003Ht$$
$$R^2 = 0.89,\ Sy{\cdot}x = 0.14 \quad (3)$$

$$\text{D.b.h. (100 largest trees/acre)} = 1.949 - 0.00008132\ T + 503.8/T + 0.09565Ht$$
$$R^2 = 0.75,\ Sy{\cdot}x = 0.25 \quad (4)$$

These equations account for 75 to 95 percent of the variation in mean diameters. Figure 1 shows that there is a fairly constant slope to all curves at densities above 1,400 trees per acre. The curve for diameter of all trees has more slope than curves for dominant trees or the 100 largest. At low densities all curves turn upward sharply.

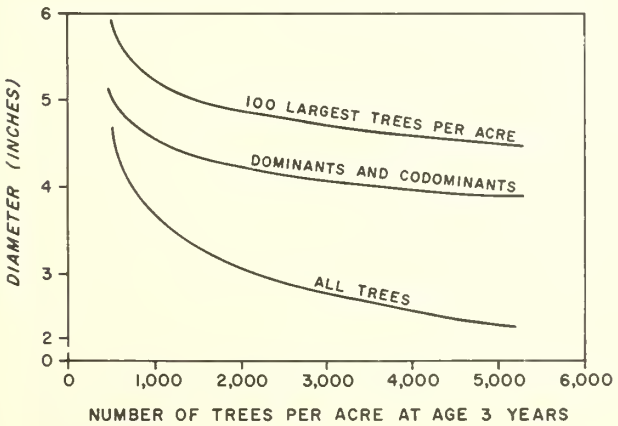

Figure 1.—*Mean diameters at age 12 years in relation to stand density after precommercial thinning at age 3.*

Average annual diameter growth of all trees from age 8 to 12 years also was inversely related to stand density. Treatment means, adjusted for site differences, ranged from 0.18 inch in unthinned plots to 0.47 inch in heavily thinned ones. Similarly, growth of dominants and codominants ranged from 0.31 to 0.51 inch, while the 100 largest trees per acre grew between 0.35 to 0.56 inch. Significantly faster diameter growth was attained with 500 stems per acre than with any higher density.

Stands thinned to 750 stems per acre had more than twice as many trees 5 inches d.b.h. and larger as those cut to 1,400, and five times as many as those with 2,800 stems per acre (table 2). But there were fewer trees 5 inches and larger in stands with 500 than 750 trees per acre. In terms of trees 4 inches d.b.h. and larger, selective thinning to 1,400 stems per acre ranked first and thinning to 750 trees was second. Plots thinned selectively to 500 trees per acre had fewer stems 4 inches and larger than most other treatments. Differences in number of large trees between selective and strip thinnings were small and inconsistent.

Total volume at age 12 years was directly related to stand density, ranging from 962 cu. ft. with 500 trees per acre to 1,821 cu. ft. per acre in unthinned check plots. In contrast, merchantable volumes in trees 3.6 inches d.b.h. and larger (to a 4.0 inch top) were inversely related to stand density. But merchantable volumes and comparisons between treatments are largely dependent on diameter limits. Since many more trees will reach merchantable size in the next few years, present relationships are temporary and have little application.

DISCUSSION

Three major findings are evident. First, height growth from age 8 to 12 years was influenced by thinning, with differences averaging 1.7 feet between the unthinned checks and stands cut to 500 trees per acre. Differences in total height were not significant at age 12 years, though they may become so later.

Collins [2] studied natural stands of slash pine in Georgia that were also thinned at age 3. He found that height growth during the next

[2] Collins, Arthur B., III. Density and height growth in natural slash pine. USDA For. Serv. Res. Pap. SE-27, 8 p. Southeast. For. Exp. Stn., Asheville, N. C. 1967.

Table 2.—*Cumulative number of trees per acre by 1-inch d.b.h. classes at 12 years*

Treatment	D.b.h.						
	≥1	≥2	≥3	≥4	≥5	≥6	≥7
	Number						
Unthinned check	3,737	2,717	1,430	483	50	3	
4,200 selective	3,463	2,593	1,453	436	43		
2,800 selective	2,607	2,260	1,440	537	36	3	
1,400 selective	1,337	1,287	1,084	671	164	17	
750 selective	710	710	687	644	367	60	3
500 selective	467	467	457	397	243	63	10
6.6-foot strip cut, 6.6-foot strip left	1,920	1,617	1,050	477	90	7	
6.6-foot strip plus selective	1,247	1,213	990	567	117	7	
6.6-foot strip plus deferred selective	1,333	1,296	993	553	120	13	
6.6-foot strip, mechanical	2,943	2,157	1,260	383	73	10	
Checkerboard	1,047	950	733	460	190	43	7
9.9-foot strip cut, 3.3-foot strip left	983	883	680	403	143	33	

14 years was slowed about 1 foot for each 500-tree increase in density. He concluded that height growth will not be seriously affected within the range of stand densities normally accepted for slash pine, but that site index curves should be adjusted for density effect.

Second, dominant and codominant trees at age 12 were only 0.25 inch larger in d.b.h. on plots cut to 2,500 trees per acre than on check plots with 5,000 trees. It is doubtful if the expense of thinning is justified by this small increase. In contrast, dominant trees in stands with 500 trees per acre were 1.1 inch larger than in those left unthinned. Precommercial thinnings are made to shorten rotations for large products and to hasten the time of first returns. Density should be reduced to no more than 750 trees per acre if these objectives are to be achieved.

Third, at the two densities (1,400 and 2,800 trees per acre) where both methods were tested, strip thinnings were as effective as selective. This observation is important because strips can be cleared inexpensively and rapidly with power equipment, while selective methods require considerable manpower.

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GERMINATION ANALYSES OF EXCISED EMBRYO CYLINDERS AND WHOLE ACORNS OF WATER OAK

J. A. Vozzo [1]

SOUTHERN FOREST EXPERIMENT STATION

More reliable information on respiration and chemical changes during germination of acorns can be obtained by analyzing excised embryo cylinders rather than whole acorns. Indications of processes taking place in whole acorns may be masked by the surrounding storage tissues.

Additional keywords: *Quercus nigra,* respiration, seed analysis.

Differences in respiration and chemical makeup of dormant, stratified, and germinated seeds can indicate requirements for breaking dormancy and inducing germination. Data on whole, large seeds such as oak acorns are often difficult to interpret *(3)*, and some researchers have analyzed excised embryos rather than whole acorns *(2,3,5)*. This note compares respiration rates and chemical analyses of whole water oak *(Quercus nigra* L.) acorns with those of excised embryo cylinders. Results indicate that standard data on large dormant, stratified, and germinated seeds would be more valuable if excised embryos rather than whole seeds were analyzed.

[1] Plant Physiologist at the Forest Tree Seed Laboratory, Mississippi State, Miss. The Laboratory is maintained by the Southern Forest Experiment Station in cooperation with Mississippi State University.

MATERIALS AND METHODS

Acorns were collected in October 1971 from a single tree at Mississippi State, Mississippi, and stored at 4°C. in plastic bags. Dormant acorns were taken directly from storage; stratified acorns were imbibed for 1 day at 23°C. then held for 30 days at 6°C. To germinate acorns, they were taken from stratification and placed in a variable regime germinator at 20 to 30°C. until the radicle emerged from the pericarp.

Embryos were excised from acorns with a #1 cork borer which removed a plug 3 mm. in diameter. The only precaution required during excision is to make certain that the embryo is centered in the plug. The resulting cotyledon-embryo cylinder was cut to 4-mm. long, then placed in a respirometer flask or dried for chemical analyses.

Respiration was measured in a differential respirometer. Single whole acorns were placed in 125 ml. flasks, and 2-liter flasks were immersed in an adjacent water bath as references to compensate for the large volume. Excised embryos were placed in 15 ml. flasks. Respiration was measured at 25°C. without supplemental lights, and flasks were shaken at 110

strokes per minute. Six flasks contained KOH for oxygen determination, six had buffer (pH 7.41) for carbon dioxide calculations, and two had distilled water for thermobarometer controls. After equilibration, measurements were taken every 30 minutes for 7 hours. Each trial was replicated three times, and values reported are averages from 18 acorns.

For chemical analyses, whole acorns and excised embryo cores were dried for 24 hours at 70°C., then ground in a Wiley mill to pass a 40-mesh screen. Crude fat content was determined by petroleum ether extraction. Phosphorous was analyzed by the chlorostannous-reduced molybdophosphoric blue method *(1)*. Soluble and insoluble carbohydrate and nitrogen analyses were from 80 percent ethanol extractions. Nitrogen content was measured by a micro-Kjeldahl technique, and carbohydrate by the phenol-sulfuric acid procedure *(4)*.

RESULTS AND DISCUSSION

The respiration rates of excised embryos were 10 times those of whole acorns (figs. 1a and 1b). There was little difference between oxygen consumption rates for dormant and stratified whole acorns. The increase in their respiratory quotient (RQ) (fig. 1c) was caused by an increase in carbon dioxide evolution from stratified acorns. Conversely, excised embryos of dormant and stratified acorns evolved carbon dioxide at similar rates, but the dormant material took up oxygen much faster. The relative CO_2 to O_2 ratios were similar enough to show nearly parallel RQs for whole acorns and excised embryos (fig. 1c). The ranges suggest utilization of a fat substrate in both test materials.

During germination, crude fat decreased in the excised embryo while it increased in percent dry weight in whole acorns (fig. 2a). Soluble carbohydrates and nitrogen increase in mg./g. dry weight in excised embryos while they decrease in the whole acorn (figs. 2c and 2e). These changes indicate a translocation of metabolites from cotyledons to active sites in the embryo.

In excised embryos, both respiratory quotients and chemical analyses indicate utilization of crude fat. In whole acorns percentage of crude fat changed little during germination.

Starch and other insoluble carbohydrates in excised embryos increased rapidly during stratification and rapidly declined during germination (fig. 2d). This pattern represents a build-up of stored starch in the embryo during stratification. Insoluble carbohydrate content of whole acorns rose throughout germination be-

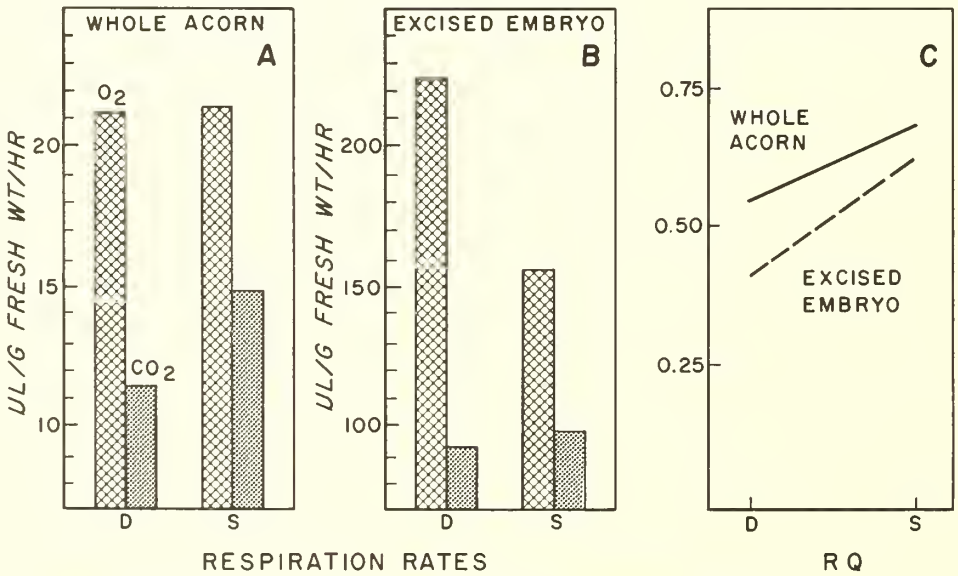

Figure 1.—*Oxygen uptake, carbon dioxide generation, and respiratory quotient (RQ) in whole seeds and excised embryos of dormant (D) and stratified (S) water oak acorns.*

cause the weights of cotyledons were declining more rapidly than those of the insoluble carbohydrates they contained.

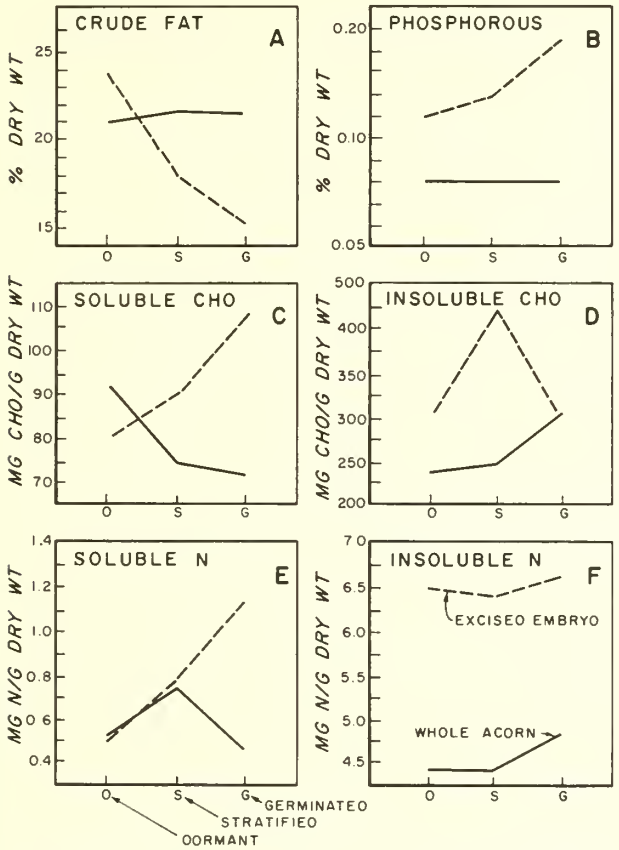

Figure 2.—*Chemical analyses of whole acorns and excised embryos of water oak.*

In embryos, soluble nitrogen generally followed the pattern observed for soluble carbohydrates; content rose during stratification and germination (fig. 2e). The active meristems of the embryo require proteinaceous material, which is high in nitrogen, for growth. The content of such material builds up throughout the seed during stratification, but is concentrated in the embryo during germination. Changes in insoluble nitrogen were about the same in whole acorns as in excised embryos (fig. 2f), but the content of insoluble nitrogen was considerably higher in embryos.

Phosphorous content of whole acorns remained constant during stratification and germination, while that of excised embryos increased (fig. 2b).

Excising the embryo from surrounding cotyledon tissue allows close observation of the embryo. In whole acorns, the metabolism of undifferentiated parenchyma of cotyledon cells influences results. The method described for excising acorn embryos is easy, and it permits observation of embryo metabolism uninfluenced by stored materials.

LITERATURE CITED

1. Jackson, M. L.
   1958. Soil chemical analysis. 498 p. Englewood Cliffs, N. J.: Prentice-Hall, Inc.
2. Jones, L., and Brown, C. L.
   1966. Cause of slow germination in cherrybark and northern red oak. Proc. Assoc. Off. Seed Anal. 56: 82-88.
3. McDermott, J. J.
   1941. A physiological study of afterripening in acorns. PhD. thesis. Duke Univ. 86 p.
4. Nalewaja, J. D., and Smith, L. H.
   1963. Standard procedure for the quantitative determination of individual sugars and total soluble carbohydrate materials in plant extracts. Agron. J. 55:523-525.
5. Thompson, D. H.
   1970. An investigation of the delayed germination of cherrybark oak (*Quercus falcata* var. *pagodaefolia* Ell.) acorns. MS thesis, Miss. State Univ. 32 p.

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BASIS CHARTS FOR SOUTHERN LUMBER AND PLYWOOD HEDGERS

Lloyd C. Irland

SOUTHERN FOREST EXPERIMENT STATION

Lumber and plywood hedgers must know the relations over time between their product prices and prices in futures markets. Sample basis charts are provided for five southern pine lumber and plywood grades and two contract (western) grades.

Additional keywords: Futures markets, lumber prices, plywood prices.

Lumber and plywood have been traded on active futures markets for 3 years. Trading in lumber began on the Chicago Mercantile Exchange in October 1969; plywood opened at the Chicago Board of Trade 2 months later. The contracts are written for rail shipments of western lumber and plywood grades, but interest in hedging southern pine is growing. This Note provides basis charts for southern pine products. It does not describe reasons for hedging, or hedging policies. The exchanges and commodity brokerage houses are the best sources of such information. Some references are listed at the back of this Note.

The author acknowledges assistance from Dr. Richard L. Sandor, Chicago Board of Trade; Mr. Thomas Harbison, Chicago Mercantile Exchange; and Mr. James Olmedo, Merrill Lynch, Pierce, Fenner & Smith, Inc., New York, N. Y.

Cash basis is the difference between the price of the near future and the cash price of the contract grade at a given time. For instance, if white fir lumber futures are trading at $140, while white fir of the contract grade is selling at $133, traders would say that the *cash basis* is $7, or 700 points. The *basis* for any noncontract item is simply the difference between the near future and cash for that item. For example, on December 31, 1970, January ½ inch CDX western (sheathing) plywood closed at $72. Basis relations were:

Item	*Cash quote*	*Basis*
½ inch CDX western	76	4 over (cash basis)
¼ inch AD interior western	66	6 under
¾ inch CDX southern	114	42 over

In this manner, producers or wholesalers can compute the current basis for any item.

In computing a basis, the hedger should enter the cash price he receives for his product in relation to futures prices. Thus, each producer has a different basis for each grade, reflecting

local demand and supply, freight rates, species, and grade. Every prospective hedger, therefore, must study the basis relationships that apply to his own net realizations, item by item.

For practical hedging, life of contract basis patterns must be studied. A sample basis computation for the September 1971 plywood contract is shown in table 1 and charted in figure 1. Similar charts showing a series of contract months are needed for planning hedging programs. The basis pattern shown in figure 1 should not be taken as typical.

Table 1.—*Basis calculation for September 1971 ½-inch CDX plywood contract*

Week	Cash	September 1971	Basis
1970			
Sept. 25	$79	$91	$12
Oct. 2	77	89	12
9	77	90	13
16	74	87	13
23	70	84	14
30	72	86	14
(Nov. 1970 through July 1971 omitted)			
1971			
Aug. 6	93	91	−2
13	88	88	0
20	94	91	−3
27	90	90	0
Sept. 3	87	85	−2
10	88	87	−1
17	87	83	−4
24	84	82	−2

The remaining charts (figs. 2-9) show the basis for the near future only, making possible a continuous time series. They show weekly price data from the *Random Lengths* weekly letter. The charts provide a rough guide to past behavior of southern pine lumber and plywood bases. They are not, however, adequate for designing hedging programs.

Figure 2 shows how the basis series can be plotted on a calendar-year scale to identify seasonal patterns for a given time. Data now available can yield only the crudest generalizations about typical basis behavior. Three years is too short a period to clearly define seasonal patterns. The rapid price fluctuations of recent years make the patterns difficult to rely on for the future. Figures 3 through 9 provide time series comparisons of cash prices, futures prices, and bases.

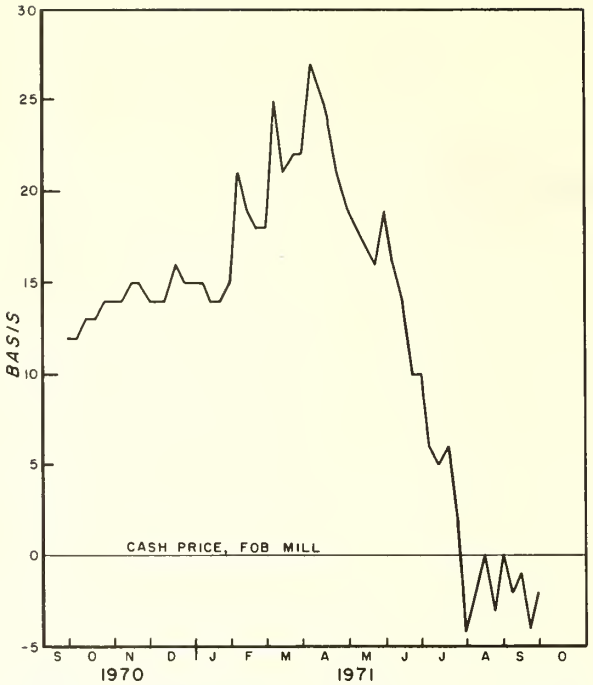

Figure 1.—*Basis chart for September 1971 plywood contract—futures minus cash price over life of contract, weekly prices.*

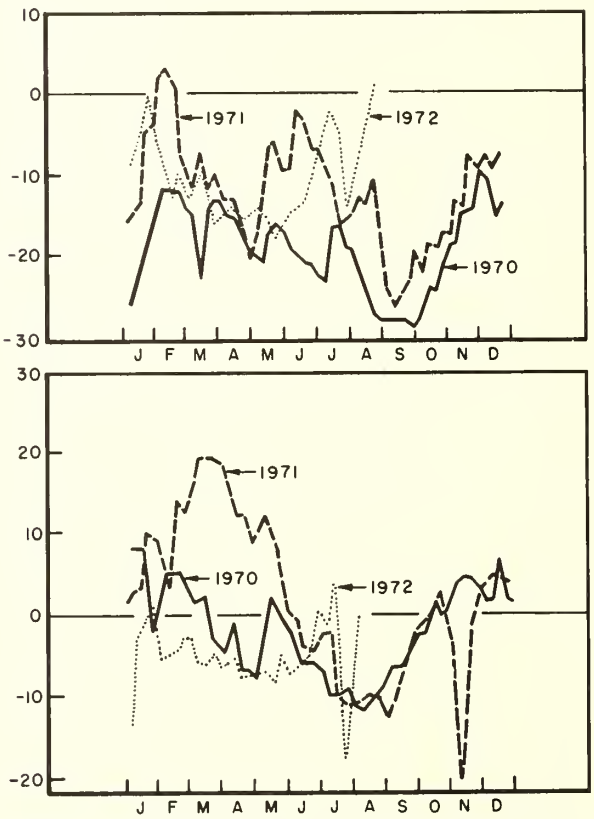

Figure 2.—*Seasonal basis patterns, southern pine items. Futures minus cash prices, weekly through August 1972.* Above: *No. 2, 2 by 4 by 8.* Below: *½ inch CDX (sheathing).*

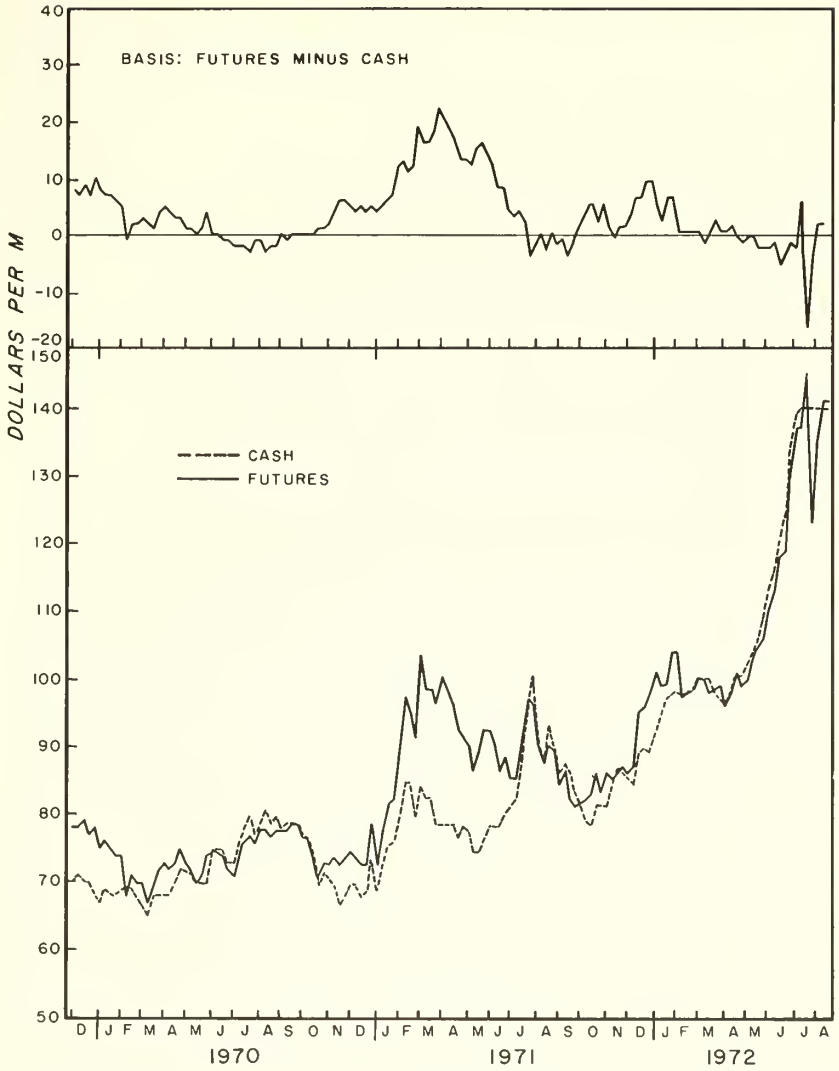

Figure 3.—*Plywood prices and cash basis, western CDX ½ inch.*

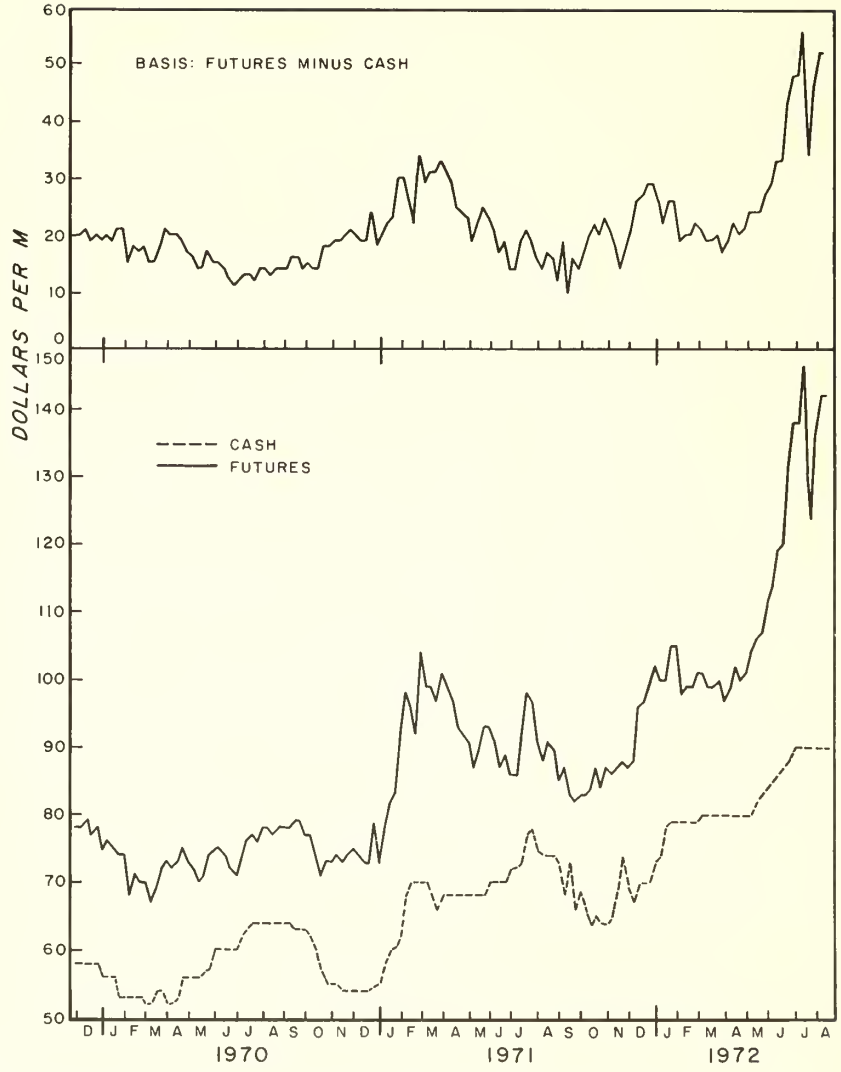

Figure 4.—*Southern pine plywood basis, CDX 5/16 inch.*

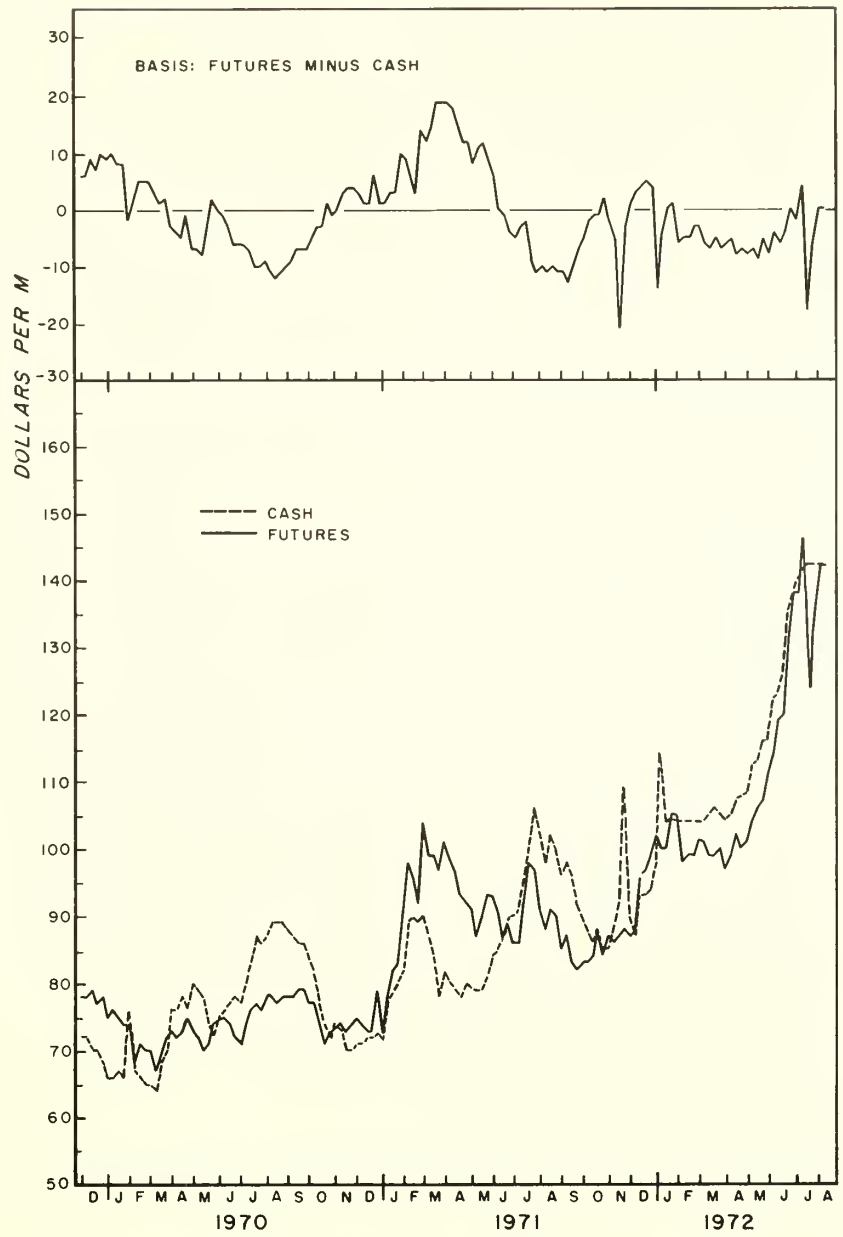

Figure 5.—*Southern pine plywood basis, CDX ½ inch.*

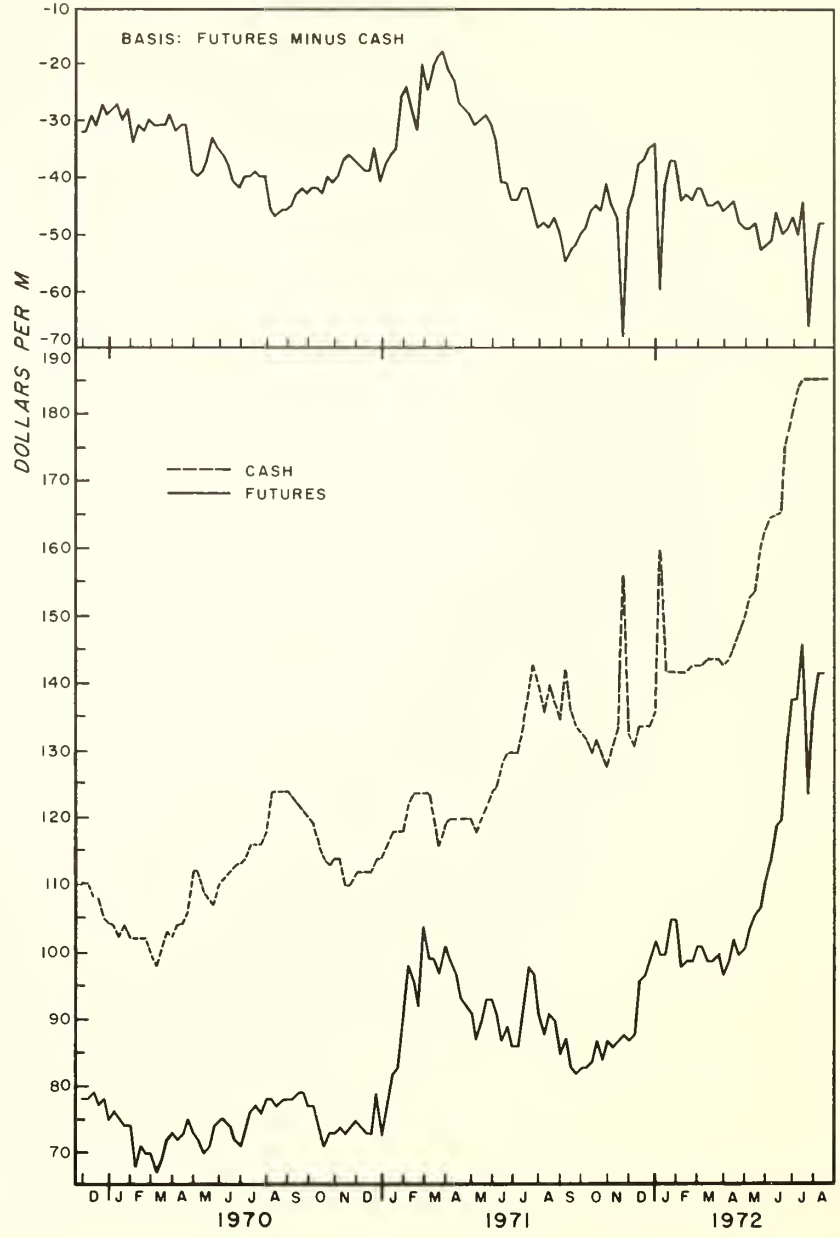

Figure 6.—*Southern pine plywood basis, CDX 3/4 inch.*

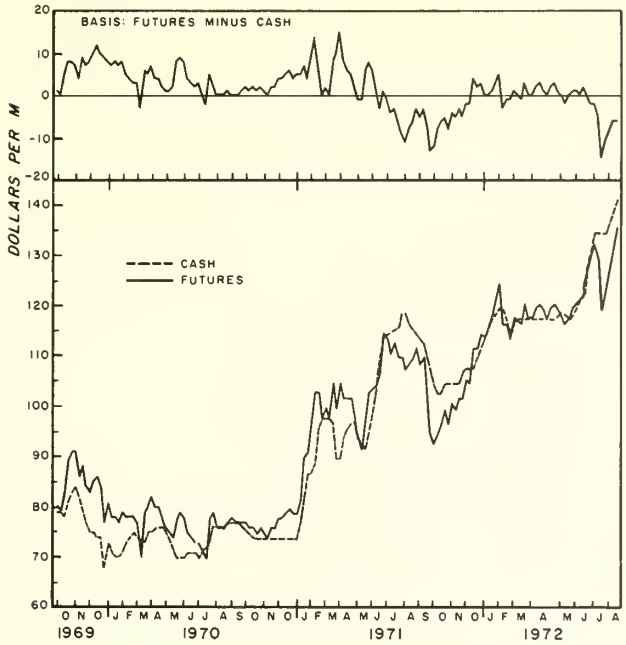

Figure 7.—*Lumber cash basis, kiln-dried white fir random dimension.*

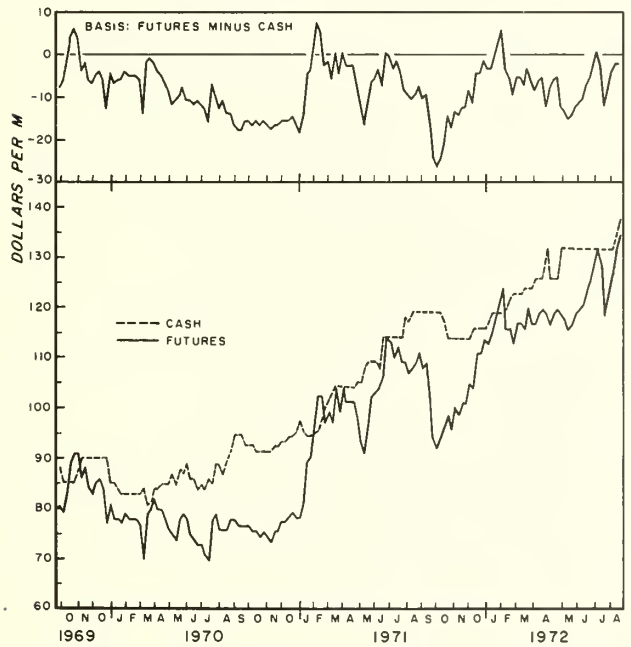

Figure 8.—*Southern pine lumber basis, No. 2 and better boards 1 by 6.*

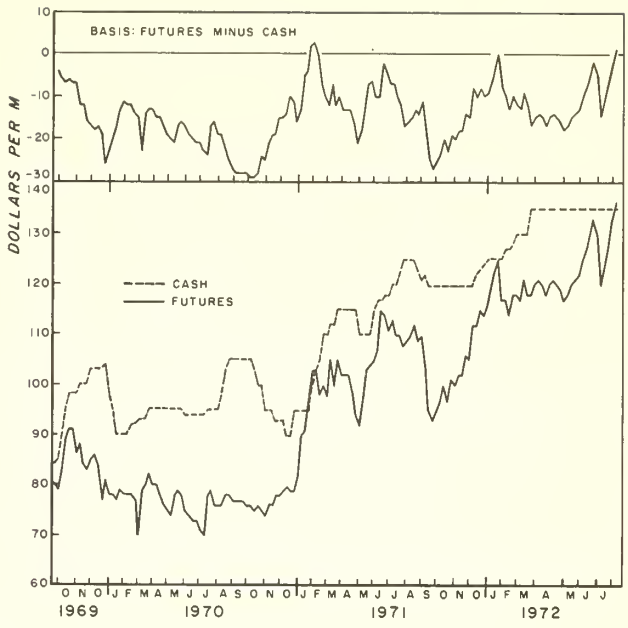

Figure 9.—*No. 2 southern pine lumber basis, 2 by 4 by 8.*

REFERENCES

Chicago Board of Trade.
1972. Statistical annual 1971. 299 p. Chic. Board Trade.
Contains contract provisions and daily futures prices.

Chicago Board of Trade.
[n. d.] Hedging highlights. 18 p. Chic. Board Trade.
Brief introduction to basis trading.

Chicago Mercantile Exchange.
1972. Fundamental factors affecting lumber. 32 p. Chic. Merc. Exch.
Describes market, lists sources of data.

Chicago Mercantile Exchange.
1972. Yearbook, 1971-72. 363 p. Chic. Merc. Exch.
Contains contract provisions and daily futures prices.

Gray, R. W.
1972. Trading in plywood futures. 26 p. Chic. Board Trade.
General introduction to plywood market.

Radoll, R. W.
1972. Hedging: plywood futures. 39 p. Chic. Board Trade.
Detailed survey of plywood hedging practices.

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CHEMICALS FAIL TO INDUCE ABSCISSION OF LOBLOLLY AND SLASH PINE CONES

B. F. McLemore [1]

SOUTHERN FOREST EXPERIMENT STATION

Several chemicals that induce abscission of fruits failed to decrease the force necessary to remove loblolly and slash cones from branches.

Additional keywords: *Pinus taeda, Pinus elliottii,* cone harvest.

Brief mechanical shaking of trees dislodges half or more of the cones from longleaf *(Pinus palustris* Mill.) and slash pine *(P. elliottii* Engelm.) (Chappell, 1969; Richardson, 1967; and Taylor, 1967), but the more tenacious cones of the loblolly *(P. taeda* L.) resist mechanical shaking. Several chemicals have induced abscission of apples, cherries, olives, and citrus fruits, thus facilitating harvest with mechanical shakers (Cooper et al., 1968). In the study described here, these chemicals were applied to loblolly and slash pines, but they did not significantly reduce the force needed to detach cones.

METHODS

Two separate studies were installed. The first included both loblolly and slash and the second loblolly only. Since effects of the chemicals are localized and translocation limited, different treatments could be applied to cone clusters on one tree. As a check, several clusters were left untreated.

In the first study, clusters on 16 slash and 9 loblolly trees were treated. The slash trees were about 20 years old, 12 to 15 inches d.b.h., and 50 feet in height. Loblolly trees were 15 to 20 years old, about 12 inches d.b.h., and 30 to 40 feet tall. Two chemicals, each at three concentrations, and three times of application were tested on each species. Ethrel[2] (2-chloroethylphosphonic acid) was applied at rates of 500, 2,500, and 5,000 p.p.m.; and ascorbic acid was tested at concentrations of 10,000, 40,000 and 70,000 p.p.m. Sufficient Tween 20, a surfactant, was added to all formulations to give a final concentration of 0.1 percent. Distilled water was used as a carrier for both chemicals. Sprays were applied either 1, 2, or 4 weeks before an assumed maturity date of September 8 for slash and October 1 for loblolly. A small hand-sprayer operated by compressed gas was

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[2] Mention of trade names is solely to identify materials used and does not imply endorsement by the U.S. Department of Agriculture.

used, and the cluster of cones and the needles on the adjoining stem were sprayed until the material dripped from cones and foliage. Each of the 18 treatment combinations was replicated three times on clusters containing two to four cones.

In the second study, 7-year-old loblolly grafts of three clones in a seed orchard were tested to minimize tree-to-tree variation. Trees about 25 feet tall and 6 inches d.b.h. were selected and subjected to 27 different treatments. Ethrel was applied at rates of 5,000, 7,500, and 10,000 p.p.m.; iodoacetic acid was tested at 500, 1,500, and 2,500 p.p.m.; and the rates for cycloheximide were 20, 60, and 100 p.p.m. Triton-X was used as a surfactant. Cones were sprayed either 1, 2, or 4 weeks before an assumed maturity date of October 5. The method of application was the same as in the first study, and each treatment was replicated three times. A supplemental study was installed to test the effects of midsummer sprays applied 10 weeks before harvest. In this instance concentrations were 5,000 p.p.m. for Ethrel, 2,500 p.p.m. for iodoacetic acid, and 100 p.p.m. for cycloheximide.

The force required to remove cones was measured on the assumed maturity dates for both studies. A Hunter mechanical force gage determined the cone removal force (CRF) to the nearest 0.1 kg. (100 g.). Cones were removed from branches by attaching a clamp and pulling parallel to the branch and away from the trunk (fig. 1). Although cones are sometimes more easily detached by pulling downward, this procedure was rejected because it often splits or breaks the branch. The CRF for each cone in a cluster was determined, and an average computed for each cluster. The cluster averages were used in statistical analysis in which treatment means were compared at the 0.05 level of probability.

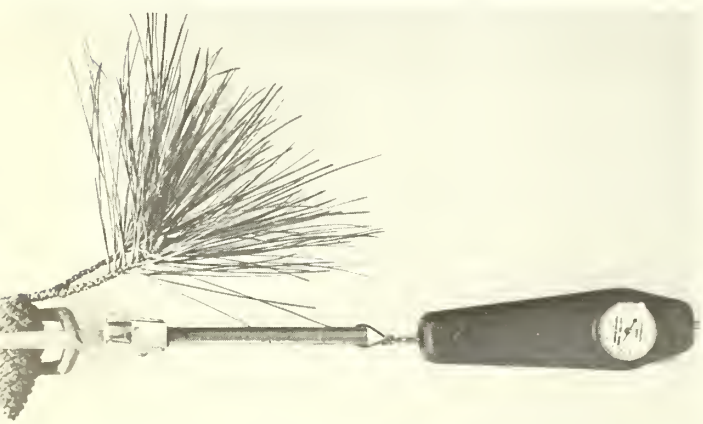

Figure 1.—*Gage used to determine kilograms of force required to detach cones from branches.*

RESULTS AND DISCUSSION

None of the treatments significantly reduced the amount of force necessary to detach loblolly or slash cones from branches (table 1). In the first study CRF's averaged about 20 kg. for loblolly cones and less than 2 for slash regardless of type of treatment. Untreated controls averaged 20 kg. for loblolly cones and 1.8 for slash.

Table 1.—*Force required to detach loblolly and slash cones in the two studies.*

Chemical	Study 1		Study 2, loblolly
	Slash	Loblolly	
	-- *Kg.* --		*Kg.*
Ethrel	1.1	20.1	19.6
Ascorbic acid	1.4	20.0	..
Iodoacetic acid	..	...	19.6
Cycloheximide	.	..	20.1
Check	1.8	20.0	21.8

As expected, slash cones were much more easily detached than loblolly cones. The principal reasons may be the longer length and greater brittleness of slash pedicels and the larger size of slash cones.

Ethrel spray killed more pedicels and caused more needle cast on slash than on loblolly trees. In the first study, 5,000 p.p.m. Ethrel killed slash pedicels when applied 4 weeks before harvest. Moreover, it resulted in almost complete abscission of slash needles older than the current year's growth and caused some loblolly needles to shed. Ascorbic acid did not kill pedicels of either species, but the 70,000 p.p.m. caused some shedding of slash needles. Spray treatments killed no yearling conelets of either species.

Wide tree-to-tree variation in the first investigation suggested the desirability of studying clonal material in subsequent tests. Since other cone and seed characteristics vary widely a-

mong trees, it is not surprising that the CRF also varies greatly. For example, average CRF's for slash trees ranged from 0.6 to 2.1 kg.; averages for loblolly trees were from 14.2 to 26.4 kg.

In the second study, the force required to pull cones from branches averaged about 20 kg. for all treatments. Untreated cones required 21.8 kg. These results agree closely with those obtained in the first study.

Spray treatments applied during late July—10 weeks prior to cone maturity—were more harmful to trees than those applied in September. July treatments resulted in extensive defoliation and in some instances killed branches. Probably the damage was severe because trees were growing more actively in July than in September.

Most of the spray treatments applied 4 weeks prior to harvest caused extensive shedding of older needles (fig. 2). This premature shedding could be beneficial if vacuum harvesters are developed. A major difficulty in vacuuming seeds on the ground is the large amount of straw picked up. This study indicates it may be feasible to cause all straw older than 1 year to shed before cones ripen. The straw could be removed from orchards prior to seed fall. The consequence of straw removal on subsequent cone production and tree vigor is unknown, but it is doubtful if trees would be harmed to any appreciable extent.

Figure 2.—*Loblolly cones and branch sprayed with 500 p.p.m. iodoacetic acid 4 weeks prior to date picture was taken. Older straw has shed from sprayed branch but is still present on unsprayed branch at left. Similar results occurred with 5,000 p.p.m. Ethrel, and more extensive defoliation occurred with 20 p.p.m. cycloheximide.*

Of the three chemicals tested, cycloheximide damaged branches most, and it is probably unsuited for spraying to cause premature needle fall. Best results with least damage were achieved with concentrations of 5,000 to 7,500 p.p.m. Ethrel or 500 p.p.m. iodoacetic acid.

Yearling conelets were not present on all branches receiving the various treatments. The only conelets harmed, however, were those where the entire branches were killed.

Failure of some of the most promising abscission-inducing chemicals to reduce CRF's in these studies, plus other research showing that pine cones lack an abscission layer, indicates a poor outlook for improving mechanical harvest of pine cones with chemicals.

LITERATURE CITED

Chappell, T. W.
[1969.] Harvesting pine cones with mechanical tree shakers. Proc., For. Eng. Conf. ASAE Pub. PROC-368, p. 65, 68.

Cooper, W. C., Rasmussen, G. K., Rogers, B. J., and others.
1968. Control of abscission in agricultural crops and its physiological basis. Plant Physiol. 43: 1560-1576.

Richardson, B. Y.
1967. Shaking trees to collect pine cones. South. Lumberman 215(2680): 140-141.

Taylor, H. T., Jr.
1967. Progress in seed-collection methods. USDA For. Serv. Southeast. Area For. Nurserymen's Conf. Proc. 1966: 67-68. USDA For. Serv. Southeast. Area, State and Priv. For.

PRECAUTIONS

This publication reports research involving pesticides. It does not contain recommendations for their use nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State or Federal agencies before they can be recommended.

SOUTHERN FOREST EXPERIMENT STATION

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LONGLEAF PINE CONE PRODUCTION IN RELATION TO SITE INDEX, STAND AGE, AND STAND DENSITY

Thomas C. Croker, Jr.

SOUTHERN FOREST EXPERIMENT STATION

FOR. TECH. & AGR.

Few cones were produced in stands less than 30 years old. In stands 30 to 70 years in age, production seemed best at timber densities of about 30 square feet of basal area per acre, and tended to increase with increasing site index.

Additional keywords: *Pinus palustris*, seed, natural regeneration.

Over the years, experience and research have given general evidence that production of cones on longleaf pine *(Pinus palustris* Mill.) varies with site quality and that release from competition stimulates cone bearing (Allen, 1953; Croker, 1952; Shoulders, 1968; Wahlenberg, 1946).

In the hope of providing specific information on these relationships, cone and seed production was studied in stands representing most of the range of longleaf. While the results are not definitive, they indicate some trends that merit further study and also contain implications for land managers.

METHODS

Cones maturing in the fall of 1971 were counted on 123 plots, each 0.05 acre in size, in even-aged stands of pure longleaf pine. Counts were made of open cones in the spring and included cones on the ground as well as those in the tree crowns. Stand densities ranged from 11 to 156 square feet of basal area per acre, ages from 18 through 82 years, and sites from 55 to 92 (50-year index). As no recent cutting had been done on the plots, the cones had matured under substantially the timber density existing when the primordia were initiated in 1969.

An effort was also made to relate number of seeds per cone to the same stand and site conditions. To this end, collections from 93 sample trees were made in 1967, 1968, and 1971. Where available, four cones were collected from each sample tree. Seeds were extracted, and means of sound seeds per cone were computed yearly. The collections sampled a good cone year (1971), a poor year (1968), and an average one (1967).

RESULTS

Cone production varied more widely than had been expected, and could not be analyzed by regression; the accompanying tables are arithmetic summaries. Tables 1 and 2 show

relations between stand age, site index, and stand density for all age classes sampled. Table 3 summarizes the combined effect of site and stand density for all stands in the age span between 30 and 69 years. Stands less than 30 and more than 69 years old were omitted from table 3 because a high proportion of the young stands were in the lightest density class, while stands above 69 years of age were too few to provide an adequate sample.

Table 1.—*Cone production per acre in relation to stand age and site index*

Age class (years)	Site index	Number of plots	Number of cones per acre	
			Mean	Standard deviation
	Feet			
<30	60	14	30	66
	70	11	84	10
	80	9	138	122
	90	6	654	974
30-49	60	6	256	609
	70	10	746	770
	80	13	822	768
	90	10	830	896
50-69	60	2	1,720	1,301
	70	18	1,251	940
	80	11	896	835
	90	0	. . .	. . .
70 +	60	4	420	337
	70	7	1,874	1,908
	80	2	270	382
	90	0	. . .	. . .

Table 2.—*Cone production per acre in relation to stand age and density*

Age class (years)	Basal area	Number of plots	Number of cones per acre	
			Mean	Standard deviation
	Sq. ft.			
<30	30	22	182	559
	60	11	146	115
	90	7	128	81
30-49	30	7	1,320	1,017
	60	10	972	840
	90	22	410	498
50-69	30	7	1,720	850
	60	8	997	1,028
	90	16	987	841
70 +	30	2	590	778
	60	3	3,093	2,570
	90	8	610	475

Table 3.—*Cone production per acre, by site class and stand density, for age classes 30 through 69 years*

Site index (feet)	Basal area	Number of plots	Number of cones per acre	
			Mean	Standard deviation
	Sq. ft.			
60	30	1	. . .	. . .
	60	3	766	750
	90	3	14	22
70	30	5	1,672	720
	60	7	1,468	900
	90	13	876	786
80	30	5	1,248	944
	60	6	1,174	828
	90	14	548	576
90	30	2	2,020	962
	60	3	434	388
	90	8	700	624

Cones were sparse on trees below 30 years of age. Those that did occur were mostly on the better sites at the lower stand densities. Some plots had no cones at all.

In stands 30 to 69 years old, production tended to rise with site index and to decline as stand density increased above 30 square feet of basal area per acre.

Numbers of seeds per cone ranged very widely and could not be related to stand or site conditions. The data did suggest that seeds number about 50 per cone in good years (i.e., in years when seedfall is above 50,000 seeds per acre), 35 in average years, and 15 in poor years (seedfall less than 20,000 per acre). These values agree roughly with those reported by Wakeley (1954).

The cone data, together with other observations by the author, indicate that the forester should plan a rotation of more than 30 years if he intends to regenerate longleaf naturally. Longer rotations are especially desirable on poor sites.

Further, it seems that cone production will be maximized if stands are thinned to about 30 square feet of basal area per acre. While not adequately tested here, still heavier thinnings would probably reduce the cone crop per acre.

LITERATURE CITED

Allen, R. M.
1953. Release and fertilization stimulate longleaf pine cone crop. J. For. 51: 827.

Croker, T. C., Jr.
1952. Early release stimulates cone production. USDA For. Serv. South. For. Exp. Stn., South. For. Notes 79.

Shoulders, E.
1968. Fertilization increases longleaf and slash pine flower and cone crops in Louisiana. J. For. 66: 193-197.

Wahlenberg, W. G.
1946. Longleaf pine. Chas. Lathrop Pack Found. and USDA For. Serv., 429 p. Washington, D. C.

Wakeley, P. C.
1954. Planting the southern pines. USDA Agric. Monogr. 18, 233 p.

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MICROBIAL INSECTICIDES CONTROL FOREST TENT CATERPILLAR IN SOUTHWESTERN ALABAMA

L. P. Abrahamson [1] **and J. D. Harper** [2]

SOUTHERN FOREST EXPERIMENT STATION

One aerial application of a commercial formulation of Bacillus thuringiensis *(Dipel or Thuricide HPC) protected water tupelo from defoliation by forest tent caterpillars. Dipel appeared to be superior to Thuricide when both were applied at the same rates with a molasses sticker.*

Additional keywords: *Malacosoma disstria, Bacillus thuringiensis, Entomophthora megasperma,* polyhedrosis virus, trichlorfon, swamp forest.

Large areas in the predominately water tupelo *(Nyssa aquatica* L.) swamp forest between the Mobile and Tensaw Rivers in southwestern Alabama have been repeatedly defoliated by forest tent caterpillars *(Malacosoma disstria* Hubner) over the past 12 or more years. The area of infestation has varied from 11,000 to 800,000 acres; about 50,000 acres were defoliated in 1972.[3] Several chemical insecticides have been tested against the insects, and ultra low volumes (ULV) of trichlorfon have proved highly effective (Abrahamson and Morris, 1973). However, since the area provides recreation, marine and freshwater fishing, and water for urban use, microbial control of the insects may be preferable to chemical control.

This paper reports preliminary tests of a commercially available bacterium, *Bacillus thuringiensis* Berlinger, and of a virus and a fungus that are indigenous to the area. Results with *B. thuringiensis* formulations were highly encouraging.

In the area, defoliation by tent caterpillars occurs in the spring, normally from late March to early May. The caterpillars hatch during spring foliation, and heavy populations strip all leaves from host trees by early May. The

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[3] Wilmore, D.H., and Hyland, J.R. Survey of forest tent caterpillar defoliation in southwest Alabama. USDA For. Serv., Southeast. Area, State and Priv. For., For. Pest Manage. Group Rep. 72-2-17, 3 p. 1972.

trees seldom die and they usually refoliate in June, but research in progress indicates that their growth for the year may be cut almost in half.

METHODS AND MATERIALS

Twelve square plots of about 20 acres each (14 × 14 chains) were established in areas of high potential infestation, which was determined by shooting branch samples from tree tops and counting egg masses. Stands that had 2.5 or more egg masses per sample branch were selected. Experience has shown that this number of egg masses yields sufficient larvae to completely defoliate the stand.

Plot corners were marked by placing parachute sections between tree tops. Markers were put in position by shooting arrows with nylon strings attached over several trees. Parachute cords were then pulled over the trees, and a chute section was hauled up and tied securely in position at two ends. These markers remained visible from the air for at least a year. Trees along the plot borders were marked with flagging for easy location during later ground checks.

Four plots were sprayed with the insecticide trichlorfon, two each at rates of 0.75 and 0.50 lb./acre. Four were treated with Dipel,[4] a wettable powder formulation of *B. thuringiensis*, two each at rates of 0.25 and 0.50 lb./acre. Two were sprayed with 1 qt./acre of Thuricide HPC,[4] a liquid formulation of *B. thuringiensis*. Nuclear polyhedrosis virus, originally isolated from dead larvae in the host population and produced by the authors in the laboratory by infecting media-reared larvae, was applied to one plot at the rate of 2.5×10^{10} polyhedral inclusion bodies per acre. Resting spores of *Entomophthora megasperma* Cohn were processed from approximately 4,000 dead larvae which were collected in the swamp area during the previous year. A final concentration of 4.2×10^{6} resting spores per acre was applied to one plot. Untreated control plots were not established, but areas adjacent to the treated plots were observed.

Water suspensions of all biological materials were prepared. Dipel, Thuricide HPC, and virus had 25 percent by volume CIB[5] added. Biofilm spreader-sticker was added to the virus and fungus suspensions. Final volumes applied were 1 gal./acre of Dipel and Thuricide, 3 gal./acre of virus, and 5 gal./acre of fungus. Trichlorfon was applied at 16 ounces and 24 ounces per acre of a ULV formulation containing 4 pounds of active ingredient per gallon.

Materials were sprayed on April 5 and 6 by a Piper Pawnee airplane fitted with roto-spin nozzles. Wind speed was below 5 m.p.h. during all applications. Spraying was monitored on April 5 from a spotter plane. At this time, caterpillars were in third or early fourth instars, and defoliation was approximately 30 percent.

Defoliation by the forest tent caterpillar was assessed on May 10, 1972. Aerial photos were taken of the plots from an altitude of 4,000 feet on Ektachrome infrared aero film (type 8443) and Ektachrome aero film (type 8442) (Ciesla, et al., 1971)[6]. Plot boundaries were superimposed on the photos. Defoliation on plots was classed as complete, partial, or negligible (protected). The final evaluation of effectiveness of products was based largely on these photos. However, each week after application the plots treated with micro-organisms were observed from the ground; the caterpillar population was sampled by shooting branches from the tree tops.

RESULTS

Ground checks 1 day and 1 week after spraying indicated that trichlorfon killed nearly 100 percent of caterpillars at both 0.50 and 0.75 pound active ingredient per acre. In one of the plots treated with 0.50 pound, a few larvae were found in partially defoliated areas between the flight lines, but no larvae were found in most of the samples. Foliage protection by trichlorfon was similar to that found in past studies (Abrahamson and Morris, 1973).

Plots sprayed with *Bacillus thuringiensis* formulations were checked 6 to 24 hours after

[4] Mention of trade names is solely to identify material used, and does not imply endorsement by the USDA.

[5] Cargill Insecticide Base (molasses sticker with other additives).

[6] We thank the Alexandria Forest Pest Management Zone Office, Southeastern Area, State and Private Forestry, for taking the aerial photographs.

spraying. Foliage samples revealed excellent coverage in most plots. Spray deposits were clearly visible on the leaves, and the water below was covered with fallen larvae. One plot treated with 0.5 pound Dipel 3 days before, contained an average of 1 larva per sample unit. Branch samples from adjacent untreated areas had populations of 50 to 200 larvae. After 6 days, very few larvae remained in the *B. thuringiensis* and trichlorfon-treated plots. A few paralyzed individuals were still on the water, indicating that the material was still active. There appeared to be more larvae remaining in plots treated with Thuricide than in those treated with Dipel. Most larvae remaining in the trees were scattered and did not congregate in masses as healthy larvae normally do. Trees in untreated areas were almost totally defoliated after 6 days, and larval masses were common.

Neither virus nor fungus provided detectable protection, although both caused significant mortality in natural populations. Larvae collected from these areas at varying intervals following spraying and maintained on artificial medium in the laboratory did not develop symptoms of the respective diseases. Only a few virus-infected larvae were recovered from bushes in the virus-treated plot, and incidence of the fungus disease in the fungus-treated plot was about the same as in the surrounding areas.

Twenty-seven days after treatment, average numbers of larvae per sample branch for individual treatments were 0.25 pound Dipel—3, 0.50 pound Dipel—1, Thuricide—17, and untreated—36.

Average foliage losses by treatment were:

Treatment	*Percent loss*
Trichlorfon (0.5 and 0.75 lb.)	30-35
Dipel (0.50 lb.)	30-35
Dipel (0.25 lb.)	35-40
Thuricide	40-50
Virus	95-100
Fungus	95-100
Untreated	95-100

At time of spraying, foliage loss was about 30 percent.

The aerial photographs showed negligible defoliation (no more than the 30 percent) in the four trichlorfon-treated plots and the 0.50 pound Dipel-treated plots. Defoliation surrounding these plots was complete. The break was sharply defined at boundaries on all plots. Areas treated with 0.25 pound of Dipel and Thuricide had narrow strips of complete to partial defoliation. Some of these areas were obviously between flight lines, an indication that the spray pilot had not accurately judged his position in treating adjacent swaths. However, some were due to lack of complete control. In one Thuricide plot, only trees that received dosages from overlapping swaths were protected. The larva population on this plot was particularly far advanced and defoliation was particularly heavy before treatment. Both factors may account for some of the apparent lack of control. The overall efficiency of the material may also have been lowered by a lack of leaves to receive the spray.

The late larval instars (third and early fourth) in most plots at time of treatment provided very rigorous test conditions, particularly for the virus and fungus, which do not kill rapidly. *Bacillus thuringiensis* at low rates, virus, and fungus may be better suited for control of first and second instar larvae. Better protection by these microbial insecticides might have been achieved and a better comparison between Dipel and Thuricide would have been possible had treatment been 7 to 10 days earlier. However, results of this test clearly show that one aerial application of *B. thuringiensis* can protect foliage from forest tent caterpillars. Dipel appeared superior to Thuricide at the same rate with CIB additives. These tests will be repeated with some modifications in 1973.

LITERATURE CITED

Abrahamson, L. P., and Morris, R. C.
1973. Forest tent caterpillar: control with ULV trichlorfon in water tupelo ponds. J. Econ. Entomol. (In press)

Ciesla, W. M., Drake, L. E., and Wilmore, D. H.
1971. Color photos, aerial sprays and the forest tent caterpillar. Photogramm. Eng. 37: 867-873.

PRECAUTION

This publication reports pesticide research. It does not contain recommendations for pesticide use nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and Federal Agencies before they can be recommended.

SOUTHERN FOREST EXPERIMENT STATION

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COMPARISON OF OLEORESIN COMPOSITION IN DECLINING AND HEALTHY LOBLOLLY PINES

John D. Hodges and Peter L. Lorio, Jr. [1]

SOUTHERN FOREST EXPERIMENT STATION

Gas chromatographic analyses of oleoresin revealed no difference in monoterpene or resin acid composition between declining and apparently healthy trees. Susceptibility of declining pines to bark beetles appears to be determined by factors other than oleoresin composition.

Additional keywords: *Pinus taeda*, southern pine beetle.

Declining loblolly pines *(Pinus taeda* L.) are common in some areas of southwest Louisiana where outbreaks of the southern pine beetle *(Dendroctonus frontalis* Zimm.) have recurred for almost a decade. Lorio (1966) reported that rootlet pathogens *(Phytophthora cinnamomi* Rands, and *Pythium* species) were associated with the decline, and suggested that affected pines serve as brood trees for destructive bark beetles.

Reduced resistance to beetle attack may be related to changes in the quantity or quality of pine oleoresin. The study reported here compared the monoterpene and resin acid composition of oleoresin from declining and apparently healthy trees.

METHODS AND MATERIALS

Sample Collection

The sample trees were on the West Bay Game Management Area in southwest Louisiana. The principal soil is Caddo silt loam, depressional phase. Declining trees were selected on the basis of appearance. They had short and yellowish needles, small cones, and sparse crowns. Height averaged 90 feet, and diameter 13 inches. Trees of about the same size and height but with healthy-looking crowns were used as controls. Some root damage by the pathogens may have occurred in the controls, but it had not progressed to the point where symptoms were visible.

In April 1971, 30 declining and 17 control trees were sampled. In April 1972, samples were taken from 30 declining and 30 control trees in the West Bay area, and also from 30 healthy trees on a well-drained site outside the

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area. No differences between years were apparent, and data presented here for West Bay are averages for the 2 years. The trees on the upland site were included not for the purpose of comparing site differences but in order to sample healthy trees from an area where rootlet pathogens were not a problem.

For comparison of radial growth, two increment cores were taken on opposite sides of each declining and healthy tree sampled in the West Bay area.

Oleoresin samples were collected by shaving most of the outer bark from a small area on each bole. A triangular cut about 2 inches on a side and with the apex downward was then made and the bark removed to expose the xylem. A small piece of aluminum foil was thumbtacked beneath the apex and shaped so as to direct the flow of oleoresin into a 10 ml. screw-top vial. The vial rested on a large staple and the aluminum foil extended slightly into the mouth of the vial, thus holding it in place.

The amount of resin collected depended on the flow rate of the tree. Usually 2 to 3 hours were sufficient to collect 3 to 10 ml. After collection the vials were sealed and placed in an ice bath for transport to the laboratory. They were then kept in a freezer until time for analysis.

Analysis of Monoterpene and Resin Acids

All analyses were performed on a Glowall 400 gas chromatograph equipped with a hydrogen flame-ionization detector.[2] The technique for analysis of terpenes was essentially the same as that of Coyne and Keith (1972), except that heptane was used as the solvent and an internal standard, P-cymene, was added to the sample to permit quantitative determination of each terpene. The glass column, 15 ft. × 1/8-inch ID, was packed with 30 percent carbowax 20 M on 60 to 80 mesh chromosorb W.

Resin acids were analyzed by the procedure of Joye and Lawrence (1967). A 16-ft. × 1/8-inch glass column packed with Versamid 900 on 60 to 80 mesh, acid-washed, DMCS-treated chromosorb W was used to separate the resin acid methyl esters. Injection port temperature was 300°C., and column and hydrogen ionization detector were at 250°C. Samples were prepared for chromatography by placing 100 mg. of resin in a 10 ml. screw-cap vial and adding 2 ml. of 0.10 N tetramethylammonium hydroxide solution and 10 mg. of arachicic acid as an internal standard.

Peak areas were determined by multiplying peak height by width at half height. Concentrations of terpenes and resin acids were determined by the formula:

$$\frac{\text{Area of internal standard}}{\text{Concentration of internal standard}} = \frac{\text{Area of sample peak}}{\text{Concentration of sample}}$$

All determinations of monoterpenes were made on the same gas chromatograph column. Because of their relatively short life, two resin acid columns were required. The second column, which was used for most of the samples collected in 1972, did not recover acids—especially those in low concentration—as completely as did the first one. This discrepancy was established by heating oleoresin samples in an oven to remove the water and volatiles and then determining total acid content. Comparisons of relative differences between declining and healthy trees were unaffected. In order to make absolute values comparable, however, data from the second column were corrected with factors obtained by comparing the peak areas of identical samples run on both columns.

RESULTS AND DISCUSSION

An examination of the increment cores taken in 1972 revealed that radial growth in the declining trees was only 25 percent of that in the apparently healthy trees. This difference would certainly indicate some adverse effect on tree physiology, but the monoterpene and resin acid composition of the oleoresin did not differ importantly between declining and healthy trees (table 1).

A second test was made in which the 10 declining trees with the slowest growth rate over the last 10 years were compared with the 10 fastest growing healthy trees. This comparison gave essentially the same results as the first. Furthermore, there appeared to be no correlation between growth rate and any of the components of the oleoresin.

In both tests, monoterpene content averaged slightly higher and the resin acid content

[2] Mention of trade names is for information only, and does not constitute endorsement by the U. S. Department of Agriculture.

Table 1.—*Resin acid and monoterpene composition of the oleoresin from declining and healthy loblolly pines. Numbers in parentheses represent observed range of values*

Oleoresin component	West Bay		Upland site	
	Declining	Healthy	Healthy typical	Healthy atypical [1]
	Percent			
Resin acids				
Pimaric acid	5.3 (2.5-8.7)	5.3 (2.9-7.5)	4.8 (2.6-7.8)	4.5 (3.8-5.2)
Sandaracopimaric	2.4 (1.2-5.5)	2.5 (1.3-4.5)	2.6 (1.5-3.6)	3.3 (2.6-3.9)
Levopimaric/palustric	36.7 (29.1-44.9)	36.1 (27.1-46.4)	34.9 (27.8-39.9)	24.2 (19.7-29.7)
Isopimaric	6.5 (2.8-11.4)	6.2 (3.6-9.8)	5.5 (3.0-10.9)	18.3 (15.9-20.4)
Unidentified	2.9 (0.9-5.8)	3.2 (1.0-6.5)	1.0 (0.4-1.9)	0.8 (0.2-1.6)
Dehydroabietic	4.3 (1.3-7.3)	4.6 (2.5-11.3)	5.8 (2.9-9.4)	8.2 (2.9-13.2)
Abietic	7.6 (5.3-12.3)	7.8 (5.8-11.3)	8.7 (6.4-10.7)	6.3 (4.8-7.1)
Neoabietic	9.3 (6.6-12.9)	8.8 (6.3-12.1)	8.7 (5.5-12.1)	11.4 (7.4-14.6)
Monoterpenes				
α-pinene	14.2 (7.6-19.7)	12.7 (7.2-19.6)	12.3 (8.4-17.2)	11.4 (9.7-13.9)
Camphene	0.2 (0.1-0.3)	0.2 (0.1-0.3)	0.2 (0.1-0.3)	0.1 (0.04-0.14)
β-pinene	8.8 (3.0-14.5)	8.8 (3.5-12.7)	9.6 (5.7-13.8)	3.9 (1.4-7.1)
Myrcene	0.7 (0.1-2.5)	0.8 (0.1-1.8)	1.0 (0.2-1.9)	0.1 (0.1-0.2)
Limonene	1.7 (0.1-4.2)	1.7 (0.1-4.2)	2.1 (0.1-4.6)	0.1 (0.05-0.2)
β-phellandrene	0.5 (0.1-1.5)	0.5 (0.1-2.1)	0.4 (0.1-1.4)	1.0 (0.1-2.6)

[1] The oleoresin in all other trees was a clear orange. The oleoresin in these four trees was clear white and very viscous.

slightly lower in declining than in healthy trees. The differences were small and are probably of no consequence in terms of susceptibility to bark-beetle attack. In other work (Hodges and Lorio, unpublished), it was found that trees subjected to moisture stress also show an increase in monoterpenes and a decrease in resin acids as compared to controls. Because of infestation by rootlet pathogens, the declining trees have greater susceptibility to moisture stress.

Chemical composition of pine oleoresin is under strong genetic control (Squillace, 1971; Hanover, 1971) and this may be the reason that no differences were observed even though changes in tree physiology were evidenced by the marked reduction in growth. Perhaps oleoresin composition remains the same even though total production within the tree is reduced.

In the present study, the trees listed as "healthy atypical" in table 1 had an oleoresin composition markedly different from that of the others. In these four pines—all on the upland site—the resin acid fraction was high and the monoterpene content low. The largest

variations were in amounts of isopimaric acid and β-pinene. Oleoresin from the four trees was clear, white, and very viscous by comparison with the clear orange resin found in most loblolly pines. Differences of such magnitude may influence the resistance of trees to beetle attack.

These four trees excepted, there was little difference in oleoresin composition between pines on the lowland site and those on the uplands.

In summary, it appears that the monoterpenes or resin acids of declining loblolly pines do not account for the increased susceptibility of the trees. Rather, the most logical explanation is based on the observation that resin production and the total oleoresin reservoir are reduced (Lorio and Hodges, 1968)—and therefore the beetle simply has less physical resistance to overcome.

LITERATURE CITED

Coyne, J. F., and Keith, G. C.
1972. Geographic survey of monoterpenes in loblolly and shortleaf pines. USDA For. Serv. Res. Pap. SO-79, 12 p. South. For. Exp. Stn., New Orleans, La.

Hanover, J. W.
1971. Genetics of terpenes. II. Genetic variances and interrelationships of monoterpene concentrations in *Pinus monticola*. Heredity 27: 237-245.

Joye, N. M., Jr., and Lawrence, R. V.
1967. Resin acid composition of pine oleoresins. J. Chem. Eng. Data 12: 279-282.

Lorio, P. L., Jr.
1966. *Phytophthora cinnamomi* and *Pythium* species associated with loblolly pine decline in Louisiana. USDA Plant Dis. Rep. 50: 596-597.

Lorio, P. L., Jr., and Hodges, J. D.
1968. Microsite effects on oleoresin exudation pressure of large loblolly pines. Ecology 49: 1207-1210.

Squillace, A. E.
1971. Inheritance of monoterpene composition in cortical oleoresin of slash pine. For. Sci. 17: 381-387.

SOUTHERN FOREST EXPERIMENT STATION

1973

U.S. FOREST SERVICE RESEARCH NOTE

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LOBLOLLY PINE FECUNDITY IN SOUTH ARKANSAS

Charles X Grano [1]

SOUTHERN FOREST EXPERIMENT STATION

Seed yields of 17 loblolly pine (Pinus taeda *L.) trees were highest when abundant spring rain and a relatively dry summer preceded flower formation. Rainfall fluctuations during this crucial period accounted for about 51 percent of the variation in annual seed production. Seed quality was best in years of high seed yield but was unaffected by time of seed release.*

Additional keywords: *Pinus taeda,* seed yields, flowering, pollen flight, rainfall effects.

In loblolly pine about 2½ years elapse between formation of flower primordia and seed release. Since the many factors influencing this complex reproductive cycle are not clearly understood, it is difficult to accurately predict or effectively increase seed yields. The present study investigated flower, pollen, cone, and seed production of loblolly pines in south Arkansas for 7 years. It also explored the effects of rainfall on seed production.

METHODS

Seven-year histories of female flower, cone, and seed production were compiled for 17 trees. During the study and for 14 years prior to it, trees had unlimited growing space. At the start of the study they ranged from 16 to 21 inches in diameter and from 38 to 81 years in age (table 4).

The trees grew on Calloway silt loam, a deep, somewhat poorly drained fragipan soil derived from loess. Site index averaged 85 feet for loblolly pine at age 50.

All pines of seed-bearing size in the vicinity of study trees were cut when the study was established. Circular plots 40 feet in radius around each tree were permanently cleared of all vegetation except grass. Two-foot-wide galvanized sheet metal shields were wrapped around the boles to prevent cone predation by squirrels.

Seed traps 1/20-milacre in area were positioned 2 feet above the ground in two concentric circles around each tree. Because conifer seedfall is generally within 35 feet of the producing tree (Siggins, 1933), four traps were located at cardinal points 17.5 feet from tree center; and eight traps were located at cardinal and intermediate points 35.0 feet from tree center. Seeds were collected at weekly intervals, and the number in each trap was recorded. These data were directly converted

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to approximate per acre yields by applying the appropriate 12-trap factor for individual tree production or a 204-trap factor for total 17-tree production. The weekly catch from all seed trees was pooled, wet-cold stratified for 90 days, and tested for 28-day germination and Czabator's (1962) germination value.

Flowers and cones were counted on nine permanently identified branches in each of five randomly selected sample trees. These data were obtained in May and September from 1964 through 1970.

Each season pollen production was determined with a continuously recording volumetric sampler (Grano, 1966) located about ½ mile from the study area. Pollen catch was recorded by 2-hour periods. Observations on dates of maximum female flower receptivity to pollen in the Crossett area were made routinely in conjunction with the Station's tree breeding program.

Weather data were recorded continuously at about 5/8 mile from the study area. For eight randomly selected trees, soil moisture at 18 inches below ground level was measured periodically with a neutron probe at each of two stations located about 5 feet from the base of the stem.

Analyses of variance were made to test for statistical significance (0.05 level) of differences in yearly and hourly pollen fall, in female flower production per year and tree, in total seed production per year and tree, and in viability or quality of weekly seed collections.

Annual seed production of individual trees was related to spring and summer rainfall in the year preceding flowering by the procedure described by Shoulders (1973) using Grosenbaugh's (1967) system for combinational screening of multivariate regressions. Independent variables in the screening were March through August rainfalls grouped as individual months or as periods of 2 to 6 consecutive months. The variables were grouped to test all possible combinations that include once and only once all monthly rainfalls between two specific points in time. One hundred nineteen sets of observations were available for analysis. The procedure isolated trends in rainfall effects. Since observations were not independent of each other, however, probability statements can not be made about the reliability of the regression equation.

RESULTS

Pollen Production

Loblolly pines shed pollen for 2.5 to 3 weeks each spring, but the starting and termination dates varied from year to year (table 1). Such a pattern is typical of southern pines (Dorman and Barber, 1956; Wasser, 1967). Pollen was shed at all hours; but dispersal was heaviest between 10:00 a.m. and 2:00 p.m., when 30 percent of the daily total fell. Lowest pollen fall—6 percent of the total—occurred between 4:00 a.m. and 8:00 a.m. Sixty-two percent fell during the daylight hours. As in other conifers (Ebell and Schmidt, 1964), pollen release was generally increased by low humidity, high temperature, and rapid or turbulent air movement.

Seed crops are sparse when pollen fall and female flower receptivity are not synchronized (Wakeley, 1954). In this study, heavy pollen fall and flower receptivity coincided every year, suggesting that lack of synchronization is infrequent in loblolly pine in south Arkansas. Forty to 70 percent of the pollen fell during the 4 days when most flowers were receptive. No relationship was found between the amount of pollen produced and the resultant viable seed crop. Bramlett's (1969) results, together with those of this study, indicate that the quantity of pollen produced by southern pines is seldom if ever inadequate.

Flower and Cone Production

Female flower production in five sample trees varied by tree and by year (table 2). All five trees were 38 years old, large and vigorous, with at least 50 percent of their total height in green crown. The smallest tree produced the most flowers while the largest tree had only average production, indicating that factors other than size were responsible for tree-to-tree variation. Probably, loblolly fruitfulness is controlled by genetic characteristics similar to those Varnell and others (1967) found operating in slash pine. Yearly variations were most likely related to fluctuations in environmental conditions.

Table 1.—*Daily loblolly pollen catch per mm.² of tape surface*

Date	Year						
	1964	1965	1966	1967	1968	1969	1970
	Number per mm.²						
March 14				7.4			
15				2.5			
16				1.2			
17				2.3			
18				2.1			
19				7.2	X [1]		
20				5.6	0.3		
21				12.1	.1		
22			2.1	33.9	X		
23			.2	41.8	X		
24	0.1	0.5	X	58.5‖	0		
25	1.7	X	X	19.4‖	1.3		1.8
26	.3	X	.1	21.7‖	6.1		X
27	1.8	0	.1	49.1‖	2.9		.1
28	2.1	0	.1	34.6	.8	7.0	.9
29	3.3	0	.4	20.5	2.8	.7	X
30	4.4	0	.7	22.9	11.7	X	.1
31	3.2	0	8.5	8.9	39.3‖	.6	1.1
April 1	26.9‖	0	20.1‖	6.9	19.7‖	16.0	3.5
2	16.6‖	.3	16.5‖		4.0‖	17.7	4.6
3	7.0‖	3.9	24.9‖		68.3‖	46.0‖	7.3
4	8.6‖	5.2	27.6‖		25.9	45.5‖	11.5
5	1.7	7.6	19.9		38.9	51.1‖	20.4‖
6	3.3	10.2	27.3		15.7	32.2‖	19.9‖
7	5.7	15.4	36.7		7.6	28.3	45.4‖
8	4.7	71.2‖	15.0		1.1	22.0	40.7‖
9	.7	34.2‖	15.6			8.9	11.4
10		26.5‖	6.3			9.0	6.4
11		6.6‖				7.4	2.0
12		2.3				2.9	
13						.8	

[1] X = less than 0.1, but greater than 0.
‖ = 4 days of highest flower receptivity.

Table 2.—*Annual production of female flowers on nine sample branches of five loblolly pine trees*

Tree (d.b.h.)	Yearly count							Total
	1964	1965 [1]	1966	1967	1968	1969	1970	
	Number							
D (18.2)	117	1,357	1,034	271	557	1,237	435	5,008
E (15.5)	296	1,529	824	57	851	1,431	603	5,591
F (21.5)	171	387	714	337	719	903	314	3,545
R (18.7)	217	656	670	284	627	774	322	3,550
T (19.7)	124	970	307	178	403	588	116	2,686
Total	925	4,899	3,549	1,127	3,157	4,933	1,790	20,380

[1] Estimate based on conelet counts and average flower loss.

Low flower production was followed 2 years later by a higher flower yield, and fewer flowers were produced 2 years after a good crop (table 3). The limited data in this study confirm a similar observation by Shoulders (1967) on flowering of longleaf pine and support Wenger's (1957) finding that loblolly seed crops influence future productivity.

Table 3.—*Flower, cone, and seed census*

Year of seed crop	Flower and cone census [1]				Total seed catch	
	Flowers: previous spring	Conelets: previous fall	Cones: spring	Mature cones: fall	Seed trapped [2]	Seed per acre
	Number					
1963				640	796	78,039
1964		763	654	486	230	22,549
1965	987	815		359	494	48,431
1966	[3] 4,700	4,054	3,980	3,617	3,333	326,764
1967	3,975	3,401	2,221	2,147	2,009	196,960
1968	1,223	1,181	971	889	1,750	171,568
1969	3,394	3,292	2,617	1,856	1,898	186,078
1970	5,346	4,549	2,234	1,905		
1971	1,868	1,367				

[1] Made on 9-10 branches in each of five sample trees to show seasonal trends. The related seed catch reported is the product of *all* the cones on all trees in the study.
[2] Product of 17 sample trees caught in twelve 1/20-milacre traps around each tree.
[3] Estimate based on full conelet count.

Abundant flowering is a prerequisite for a plentiful cone crop but does not necessarily assure it. Losses sustained between flowering and cone maturation varied from year to year. For the six crops sampled, 36 to 73 percent of the flowers yielded mature cones, for a 55 percent mean annual survival rate. Disease, insects, and adverse weather undoubtedly caused most of the losses; but no assessment of their individual roles was made. There were indications that the proportion of flowers and conelets lost between May and September is related positively to soil moisture deficiencies—i.e., that soil moisture stresses during this period promoted abortions. Monthly losses were slightly greater in the May-September interval following flowering than in any subsequent period.

Seed Production Trends

Significant differences were found in yearly as well as individual tree production (table 4). Seed crops were comparatively small in 1963, 1964, and 1965, with approximate yields of 3.6, 1.1, and 2.3 pounds of seed per acre. A bumper crop of 15.3 pounds per acre was produced in 1966. Seed was also plentiful in 1967 through 1969, when yields were 9.2, 8.0, and 8.7 pounds per acre. These yields assume a density of approximately nine seed trees per acre and reflect an average of 21,400 seed per pound.

Wenger's (1957) observations in the Southeast suggested that a large crop in 1 year is followed by a small crop 2 years later and vice-versa. The 1966 bumper crop at Crossett followed a very light one 2 years earlier. However, three plentiful seed years immediately followed the bumper year, indicating that good seed crops in 1 year do not necessarily portend inadequate ones 2 years later.

Trees tended to rank as above or below average producers quite consistently regardless of the size of the flower or seed crop. Trees F and S, for example, produced above average numbers of seeds in all years, but trees J, L, Q, and T always produced fewer than average (table 4). Other investigations have revealed similar findings (Downs, 1947; Grano, 1957).

Large annual crops and high seed quality went hand-in-hand (table 5). Data are too few and polarized to define a relationship curve, but they agree with findings reported elsewhere for southern pines (Bramlett, 1965; Wenger and Trousdell, 1958). Contrary to reports from other sources (Jemison and Korstian, 1944), the viability of seed shed at different weekly periods throughout a season did not differ significantly. Seedfall started early in October each year. Thirty-four percent fell by the end of October, 74 percent by the end of November, and 87 percent by the end of December. Beyond this point and well into

Table 4.—*Total yearly seed catch from each tree* [1]

Tree	1963		Season							Total count	Per acre	
	Diameter	Age	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70		Total	Seasonal average
	Inches	*Years*	*Number*									
A	18.6	46	29	14	3	97	37	44	87	311	30,490	4,356
C	17.7	58	57	10	19	195	69	79	96	525	51,470	7,353
D	18.2	38	41	19	20	333	307	79	159	958	93,921	13,417
E	15.5	38	40	16	36	327	236	53	83	791	77,549	11,078
F	21.5	38	57	14	40	317	216	187	203	1,034	101,372	14,482
G	19.0	77	54	30	24	221	194	84	82	689	67,549	9,650
H	17.3	38	37	5	57	302	163	161	184	909	89,117	12,731
I	18.2	41	20	8	107	364	115	274	177	1,065	104,413	14,916
J	20.3	42	39	9	11	121	68	60	62	370	36,274	5,182
L	19.8	44	45	7	6	58	33	32	46	227	22,255	3,179
M	19.1	81	81	6	16	50	37	42	72	304	29,804	4,258
N	20.2	76	70	17	24	113	47	75	105	451	44,216	6,317
P	21.1	42	57	8	16	108	66	64	92	411	40,294	5,756
Q	17.6	41	31	4	14	169	82	68	79	447	43,823	6,260
R	18.7	38	23	16	16	184	86	116	134	575	56,372	8,053
S	17.3	37	94	46	80	294	221	294	202	1,231	120,686	17,241
T	19.7	38	21	1	5	80	32	38	35	212	20,784	2,969
		Total count	796	230	494	3,333	2,009	1,750	1,898	10,510	. . .	. . .
		Per acre	78,039	22,549	48,431	326,764	196,960	171,568	186,078	1,030,389	1,030,389	147,198

[1] Twelve 1/20-milacre traps used around each tree.

Table 5.—*Annual seed production and quality*

Year	Seed yield per acre		Seed germination in a 28-day period		Viable seed per acre	Germination value
	Total	Full seed	All seed	Full seed		
	– Thousands –		*– – Percent – –*		*Thousands*	
1963	78.0	44.8	47.8	83.2	37.3	6.96
1964	22.5	14.4	37.4	58.5	8.4	6.00
1965	48.4	29.1	59.8	99.3	28.9	24.27
1966	326.8	270.6	80.9	97.7	264.4	30.63
1967	197.0	161.5	79.1	96.5	155.8	36.21
1968	171.6	137.8	79.2	98.6	135.9	41.37
1969	186.1	140.1	72.8	96.7	135.5	39.65

April, seedfall was erratic and of little consequence. Generally, the heaviest seedfall took place during the last 2 weeks of October and the first 2 weeks of November.

Rainfall-Seed Yield Relationship

Rainfall in the spring and summer of the year preceding flowering accounted for approximately 51 percent ($R = 0.71$) of the variation in the annual production of viable seed by individual trees. The standard error of the estimate was ± 50.8 seeds.

Separate regression coefficients were required for March, April, and May, and for June through August rainfall to obtain the best fit, because the seed production response to rainfall differed by season. The regression clearly indicates that viable seed yields increased with increasing March, April, and May rainfall and decreasing June through August rainfall. Shoulders (1973) found a similar relationship between slash pine flower production and rainfall in the period immediately preceding bud formation, except that flower production of unfertilized trees usually increased with increasing February through April rain and decreasing May through July rain. Dewers and Moehring (1970) reported that loblolly pine trees in east Texas subjected to April-June irrigation and July-September drought bore significantly more conelets the

following year than control or April-September irrigated trees. These results and those of the present study indicate that viable seed yields of loblolly pine are favored by a combination of abundant spring rainfall and a relatively dry summer in the year preceding flowering.

DISCUSSION

The study showed clearly that loblolly seed yields were not limited by pollen supply, that most seeds were dispersed in ample time for prompt spring germination, and that seed quality remained uniform throughout the entire period of dispersal.

High seed yields are always preceded by prolific flowering; therefore, it is reasonable to assume that the factors which favor flower production automatically benefit seed yields. Relatively high concentrations of carbohydrates are apparently necessary for flower bud initiation (Kramer and Kozlowski, 1960; Fraser, 1958). Vegetative growth increases photosynthesis and current carbohydrate production by adding to the tree's needle surface (Kramer, 1958). But flowers cannot compete for carbohydrates as successfully as vegetative growth and maturing cones can (Loomis, 1953), and flower bud initiation usually correlates with a slowdown or cessation of vegetative growth (Kramer and Kozlowski, 1960).

Plentiful spring rain increases the production of carbohydrates by stimulating vegetative growth and increasing photosynthetic capacity. A moderate moisture stress in the summer would curtail further vegetative growth without seriously reducing photosynthesis and thereby favor accumulation of readily available carbohydrates when they are needed by developing flower buds. Normally 85 percent or more of loblolly shoot elongation takes place by the end of June (Williston, 1951). However, heavy summer rainfall usually results in continued cambial activity and diameter growth (Moehring and Ralston, 1967), which deplete carbohydrate reserves to the detriment of flower production. These conclusions are supported by Hodges and Lorio's (1969) results which showed that drastically reducing soil moisture supply after mid-May markedly reduced diameter growth of 40-year-old loblolly pines and caused carbohydrates to accumulate in the inner bark.

Practical applications of the rainfall analysis are obvious. Seed orchard yields may be improved by supplementing natural rainfall in spring and then withholding supplemental water in summer. Furthermore, a knowledge of rainfall patterns would enable the forest manager to predict seed crops more than 2 years in advance; he could then begin site preparations early enough to take full advantage of natural seedfall.

LITERATURE CITED

Bramlett, D. L.
1965. Shortleaf pine seed production in the Piedmont. USDA For. Serv. Res. Note SE-38, 4 p. Southeast. For. Exp. Stn., Asheville, N. C.

Bramlett, D. L.
1969. Factors affecting seed production of shortleaf pine *(Pinus echinata* Mill.) in the Virginia Piedmont. PhD. Thesis, Va. Polytech. Inst., 82 p.

Czabator, F. J.
1962. Germination value: an index combining speed and completeness of pine seed germination. For. Sci. 8: 386-396.

Dewers, R. S., and Moehring, D. M.
1970. Effect of soil water stress on initiation of ovulate primordia in loblolly pine. For. Sci. 16: 219-221.

Dorman, K. W., and Barber, J. C.
1956. Time of flowering and seed ripening in southern pines. USDA For. Serv. Southeast. For. Exp. Stn., Stn. Pap. 72, 15 p.

Downs, A. A.
1947. Choosing pine seed trees. J. For. 45: 593-594.

Ebell, L. F., and Schmidt, R. L.
1964. Meteorological factors affecting conifer pollen dispersal on Vancouver Island. Can. Dep. For., Dep. For. Publ. 1036, 28 p.

Fraser, D. A.
1958. The relation of environmental factors to flowering in spruce. *In* The physiology of forest trees, p. 629-642. (K. V. Thimann, ed.) N. Y.: The Ronald Press.

Grano, C. X.
1957. Indices to potential cone production of loblolly pine. J. For. 55: 890-891.

Grano, C. X.
1966. An eight-day volumetric pollen sampler. USDA For. Serv. Res. Note SO-35, 4 p. South. For. Exp. Stn., New Orleans, La.

Grosenbaugh, L. R.
1967. REX—Fortran-4 system for combinatorial screening or conventional analysis of multivariate regressions. USDA For. Serv. Res. Pap. PSW-44, 47 p. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.

Hodges, J. D., and Lorio, P. L., Jr.
1969. Carbohydrate and nitrogen fractions of the inner bark of loblolly pines under moisture stress. Can. J. Bot. 47: 1651-1657.

Jemison, G. M., and Korstian, G. F.
1944. Loblolly pine seed production and dispersal. J. For. 42: 734-741.

Kramer, P. J.
1958. Photosynthesis of trees as affected by their environment. *In* The physiology of forest trees, p. 157-186. (K. V. Thimann, ed.) N. Y.: The Ronald Press.

Kramer, P. J., and Kozlowski, T. T.
1960. Physiology of trees. 642 p. N. Y.: McGraw-Hill.

Loomis, W. E.
1953. Growth correlations. *In* Growth and differentiation in plants, p. 197-217. (W. E. Loomis, ed.) Ames, Iowa: Iowa State Coll. Press.

Moehring, D. M., and Ralston, C. W.
1967. Diameter growth of loblolly pine related to available soil moisture and rate of soil moisture loss. Soil Sci. Soc. Am. Proc. 31: 560-562.

Shoulders, E.
1967. Fertilizer application, inherent fruitfulness, and rainfall affect flowering of longleaf pine. For. Sci. 13: 376-383.

Shoulders, E.
1973. Rainfall influences female flowering of slash pine. USDA For. Serv. Res. Note SO-150, 7 p. South. For. Exp. Stn., New Orleans, La.

Siggins, H. W.
1933. Distribution and rate of fall of conifer seeds. J. Agric. Res. 47: 119-128.

Varnell, R. J., Squillace, A. E., and Bengtson, G. W.
1967. Variation and heritability of fruitfulness in slash pine. Silvae Genet. 16: 125-128.

Wakeley, P. C.
1954. Planting the southern pines. USDA Agric. Monogr. 18, 233 p.

Wasser, R. G.
1967. A shortleaf and loblolly pine flowering phenology study. Va. Div. For. Occas. Rep. 28, 2 p.

Wenger, K. F.
1957. Annual variation in the seed crops of loblolly pine. J. For. 55: 567-569.

Wenger, K. F., and Trousdell, K. B.
1958. Natural regeneration of loblolly pine in the South Atlantic Coastal Plain. USDA Prod. Res. Rep. 13, 78 p.

Williston, H. L.
1951. Height growth of pine seedlings. USDA For. Serv. South. For. Exp. Stn., South. For. Notes 71, 4 p.

SOUTHERN FOREST EXPERIMENT STATION

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U.S. FOREST SERVICE RESEARCH NOTE

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EXTENDED PLANTING SEASONS FOR SYCAMORE AND COTTONWOOD

C. B. Briscoe [1]

SOUTHERN FOREST EXPERIMENT STATION

Cuttings of sycamore and cottonwood can be planted successfully in wet soil from October until bud break in the spring. Sycamore seedlings can be planted all year if available soil moisture exceeds evapotranspiration. Dormant seedlings survived summer planting better than did freshly lifted seedlings.

Additional keywords: *Platanus occidentalis, Populus deltoides,* planting time.

Because the winter planting season combines miserable working conditions with insufficient time for setting trees, planters are eager to extend its customary limits. The study described here was undertaken to determine how the month of planting influenced survival and first-year growth of sycamore seedlings and cuttings and cottcnwood cuttings in the vicinity of Stoneville, Mississippi.

[1] The author is stationed at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Mississippi, by the Southern Forest Experiment Station, USDA Forest Service, in cooperation with the Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group.

METHODS

For 4 consecutive years American sycamore *(Platanus occidentalis* L.) and eastern cottonwood *(Populus deltoides* Bartr.) were planted in randomized complete blocks. Except as indicated below, both species were treated alike.

Cuttings 20 inches long and of mixed diameter were taken from the main stem of year-old sprouts. Seedlings were pruned to a 4-inch top and a 6-inch taproot, with all lateral roots removed.

Stock for the first year's planting was prepared in the morning, stored with root or basal portion in water for 1 to 3 hours, then planted in the afternoon of the same day. In the 3 subsequent years, stock was prepared, left in water overnight, and planted the following day.

The only exception was the dormant sycamore seedlings planted during the growing season. They were lifted during late winter and kept at 33-38°F. in a dark room until the day before planting. They were then removed from cold storage, pruned, and stored in water overnight in the same manner as the freshly lifted seedlings.

All planting sites were within 20 miles of Stoneville, Mississippi (approximately 33°20′ north latitude). A new location was used each year; plantings were made on Sharkey clay loam the third year and on Commerce silt loam the other 3 years.

Trees were planted in bare soil and cultivated through the first growing season.

During the first 2 years systematically selected trees were lifted at the end of each month to assess root development.

In the first year, 1967-68, planting began in October and ended in April, on the assumptions that October was actually too early and April too late. These assumptions proved false, and planting was extended further into the growing season during the next 3 years. The months tested each year are indicated in tables 1 to 4.

Table 1.—*Summary of measurements in November 1968*

Month of planting	Height	Diameter	Survival
	Feet	*Inches*	*Percent*
COTTONWOOD CUTTINGS			
February	14.9a [1]	1.6a	95a
October	14.4a	1.6a	94a
January	13.9ab	1.5a	91a
March	13.4ab	1.4a	96a
December	12.6 bc	1.4a	85a
November	12.5 bc	1.4a	81a
April [2]	11.5 c	1.6a	50 b
SYCAMORE SEEDLINGS			
February	8.4a	1.2a	98a [3]
October	8.0ab	1.2a	97a
January	8.0ab	1.2a	98a
March	8.0ab	1.2a	100a
November	7.6ab	1.2a	100a
December	7.3 b	1.1ab	99a
April [2]	6.1 c	1.0 b	100a

[1] Within columns, values not followed by the same letter are significantly different at the 95-percent level of probability.
[2] Leafed out.
[3] All sycamore mortality was associated with mechanical damage during cultivation.

Plots were saturated before planting in 1967-68. In addition, from mid-November until April half of each plot was flood irrigated with 1 to 2 inches of water after any calendar week with less than 1 inch of rain.

Table 2.—*Summary of measurements in November 1969*

Month of planting	Planting stock		
	Cottonwood cuttings	Sycamore	
		Seedlings	Cuttings
MEAN HEIGHT OF SURVIVORS (FEET)			
August	15.4a [1]	5.0a	4.8a
September	9.0 b	4.0 c	4.3ab
October	7.7 d	4.9a	3.1 f
November	8.7 bc	4.4 b	3.8 bcde
December	8.0 cd	4.5 b	3.9 bcd
January	7.7 d	4.5 b	4.0 bc
February	8.1 cd	4.8a	3.3 def
March	7.6 d	4.5 b	3.0 f
April [2]	7.7 d	4.4 b	3.4 cdef
Average	8.9	4.6	3.7
SURVIVAL (PERCENTAGE)			
August	1 e	18 c	17 e
September	26 d	81 b	43 d
October	67 c	100a	83ab
November	92ab	100a	86ab
December	86ab	99a	89a
January	83 b	99a	46 d
February	88ab	98a	60 cd
March	92ab	98a	80ab
April [2]	95a	95a	69 bc
Average	76	88	64

[1] Within columns, values not followed by the same letter are significantly different at the 95-percent level of probability.
[2] Buds just opening.

Table 3.—*Survival in November 1970, percentage*

Month of planting	Planting stock		
	Cottonwood cuttings	Sycamore	
		Seedlings	Cuttings
August	8	21	8
September	4	70	4
October	69	100	69
November	85	92	60
December	67	94	75
January	79	100	52
February	77	94	67
March	81	94	79
April [1]	0	94	6
May	0	23	0
June	1	88	2
July	5	81	8

[1] Leafed out.

The second year, plots were not irrigated before planting. One block (one-fourth of the plots) was irrigated three times during the winter when the soil felt dry to the touch.

Table 4.—*Survival in November 1971, percentage*

Month of planting	Planting stock			
	Cuttings		Sycamore seedlings	
	Cotton-wood	Sycamore	Fresh	Dormant
March	88	88	100	100
April [1]	52	44	92	90
May	0	0	12	100
June	12	4	80	100
July	0	4	4	76
August	0	4	48	96

[1] Leafed out.

There was no irrigation in the third and fourth years.

All measurements were made after one growing season. Any plant with a green, nonwilted leaf was assumed to be alive. Diameter 4 inches above the groundline was measured to the completed tenth-inch; height of all surviving trees was measured to the completed tenth-foot. The number of trees per plot and the number of replications of plots varied from year to year. However, the individual figures in tables 1 to 4 are based on measurements of 32 to 192 trees each.

Since no significant differences in survival, height, or diameter resulted from winter irrigation, measurements of irrigated and nonirrigated trees were pooled (tables 1 and 2). Survival and size differences were tested for statistical significance for the first 2 years (tables 1 and 2); however, the pattern of survival was so clear in the last 2 years (tables 3 and 4) that statistical tests seemed superfluous.

RESULTS AND DISCUSSION

Lifting selected trees each month revealed that roots grow throughout the year in the Stoneville area.

Cuttings of both cottonwood and sycamore behaved in a similar manner (tables 1 to 4). Some rooted throughout the year, but survival was highest for those planted in wet soil from October through March. Within that period survival and growth rates were consistently good.

Fewer cuttings rooted successfully after trees leafed out in the spring, and the overall growth for spring plantings was significantly less than that of cuttings planted earlier.

Summer planting of cuttings in dry soil was virtually fruitless (tables 2 to 4). The few that survived an August or September planting grew more than those planted later (table 2), possibly because of the early start gained by root establishment in the fall or because low survival in the plots had greatly reduced intraspecific competition.

Sycamore seedlings were planted successfully throughout the year (tables 1 to 4). However, survival varied directly with soil moisture; survival was low if the soil was dry. During the growing season, survival rates were better for dormant seedlings than for freshly lifted seedlings (table 4); the difference was less marked, however, when seedlings were planted in wet soil.

RECOMMENDATIONS

Cuttings of cottonwood and sycamore can be planted in wet soil from October until bud break in the spring.

Sycamore seedlings can be planted all year if available soil moisture exceeds evapotranspiration. Summer planting is more consistently successful with dormant seedlings than with freshly lifted stock. Neither will survive inadequate soil moisture.

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WEIGHTING TREE VOLUME EQUATIONS FOR YOUNG LOBLOLLY AND SHORTLEAF PINES

Glendon W. Smalley [1]

SOUTHERN FOREST EXPERIMENT STATION

Weighting by $(D^2H)^{-2}$ stabilized variance and improved efficiency of tree volume regressions. Weighting by $(D^2H)^{-1}$ was slightly less effective. Differences between relative efficiency were small except for inside-bark regressions for trees ≥ 0.6 inch d.b.h.

Additional keywords: *Pinus taeda, Pinus echinata,* index of fit.

Equations for predicting cubic-foot volume from the product of diameter squared and height have been developed for 10- to 35-year-old loblolly *(Pinus taeda* L.) and shortleaf pines *(P. echinata* Mill.) in plantations in middle Tennessee, northern Alabama, and northwestern Georgia (Smalley and Bower, 1968a, b). This paper describes fitting of a tree volume model for these trees. Stability of variance in weighted and unweighted forms was compared, homogeneity of regression coefficients across physiographic provinces was tested, and slope and intercept characteristics of the final volume equations were observed.

METHODS

The published volume tables were based on felled tree measurements of 196 loblolly and 168 shortleaf pine trees ≥ 5.0 inches d.b.h. (table 1). Separate equations were fitted for a larger sample that also included 144 loblolly and 137 shortleaf pines 0.6 to 4.9 inches d.b.h.

Inside (IB) and outside bark (OB) diameters were measured at intervals of 5 feet or less up to 4-inch, 3-inch, and 2-inch tops OB. Total height was recorded. Individual bolt volumes were computed by the paraboloid formulas:

$$VOB = 0.0027271 [(DOB)^2 + (dob)^2]L \text{ and} \quad (1)$$

$$VIB = 0.0027271 [(DIB)^2 + (dib)^2]L, \quad (2)$$

where

VOB = volume outside bark in cubic feet;

VIB = volume inside bark in cubic feet;

DOB = diameter outside bark, large end, in inches;

[1] Soil Scientist stationed at the Silviculture Laboratory which is maintained at Sewanee, Tenn., by the Southern Forest Experiment Station in cooperation with the University of the South. Valuable assistance in analysis was provided by David R. Bower, formerly Mathematical Statistician, Southern Forest Experiment Station, New Orleans, La.; now Forest Biometrician, Weyerhaeuser Research Center, Centralia, Wash.

dob = diameter outside bark, small end, in inches;

DIB = diameter inside bark, large end, in inches;

dib = diameter inside bark, small end, in inches; and

L = length of bolt in feet.

VOB and VIB for the total stem and for 2, 3, and 4-inch OB top diameters were summarized for each tree.

Initially, tree data were grouped by physiographic province: Ridge and Valley, Cumberland Plateau, Eastern Highland Rim, and Western Highland Rim (Fenneman, 1938). Independent variables in the volume model were D, D^2, D^3, H, DH, D^2H, $D^{-1}H$, $\log_{10}(D^2H)$, H_c, and $(H-H_c)\,H^{-1}$ where

D = diameter, b.h., OB, in inches,

H = total tree height in feet, and

H_c = height to live crown in feet.

Results of stepwise fittings of the loblolly data for all utilization levels and provinces and for combined provinces, showed that D^2H was always present and accounted for 97 to 99 per-

Table 1.—*Distribution of sample trees by species, diameter, and total height classes*

Species and d.b.h. (inches)	Total height in feet														Total
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	
	Number of trees														
Loblolly															
1	4	6	1												11
2		3	16	6	4										29
3		1	5	14	13	10									43
4			3	7	13	8	6	4	3						44
4.6-4.9			1	1	2	4	6	2	1						17
Total	4	10	26	28	32	22	12	6	4	0	0	0	0	0	144
5.0-5.5				1	6	11	10	6	4	2					40
6				1	2	8	7	15	4	2	2				41
7						3	8	6	11	5	2	3			38
8						7	8	4	5	5	7	2			38
9							5	3	2	4	6	4			24
10								2		1	4	2			9
11											1	1	2		4
12												1			1
13															0
14														1	1
Total	0	0	0	2	8	29	38	36	26	19	22	13	2	1	196
Shortleaf															
1	2	2	1												5
2		5	13	10	3										31
3		2	3	7	14	8	3								37
4				12	5	11	8	5							41
4.6-4.9			1	7	4	2	5	3		1					23
Total	2	9	18	36	26	21	16	8	0	1	0	0	0	0	137
5.0-5.5				1	4	8	7	6	3	2					31
6				3	8	6	10	6	8	3	1				45
7					1	4	7	8	9	7	1				37
8							3	4	13	7	1	1			29
9						1	2	3	4	6	2	1			19
10									2		1				3
11											1		1		2
12											1				1
13										1					1
Total	0	0	0	4	13	19	29	27	39	26	8	2	1	0	168

cent of the total variation. Additional variables increased r^2 less than 1 percent and different sets were present from one province to the next. Therefore the single independent variable D^2H was used in all further comparisons for both species. An intercept was also included to give the model more flexibility in fitting the data.

Grouping the data into D^2H classes indicated that the variance of volume increased with increase in D^2H. Three weights, 1, $(D^2H)^{-1}$, and $(D^2H)^{-2}$, were compared. To weight the residuals in this way, both sides of the volume equations were multiplied by the square root of the appropriate weight and the transformed models were fit to the basic data.

Model	Weight	
$V = b_0 + b_1 D^2H$	1	(3)
$V(D^2H)^{-\frac{1}{2}} = b_0(D^2H)^{-\frac{1}{2}} + b_1(D^2H)^{\frac{1}{2}}$	$(D^2H)^{-1}$	(4)
$V(D^2H)^{-1} = b_0(D^2H)^{-1} + b_1$	$(D^2H)^{-2}$	(5)

Since the dependent variable was transformed in equations (4) and (5), the index of fit "I" suggested by Furnival (1961) was used to compare the equations.

Initially, the minimum threshold d.b.h. for each utilization level was set 1 inch larger than the minimum top diameter OB. As a result, sample size decreased as stem utilization decreased. Subsequently, the threshold d.b.h. was held constant at 5.0 inches to escape problems of intersection by various volume category regressions at large values of D^2H.

For simplicity, results are presented only for regressions with all provinces combined. This step is justified because statistical tests showed that weighted individual province regressions for each species did not differ in slope or intercept.

RESULTS

Weighting consistently improved the regressions (table 2). In all cases, IB regressions had slightly higher relative efficiencies than OB regressions for both species. Reducing the proportion of the tree utilized decreased the relative efficiencies of both weights. This decrease is probably due to the use of a constant threshold d.b.h. for all utilization levels. The expected changes in relative efficiencies if threshold diameters had varied can be seen in the comparison of total volume equations for the two sample sets—trees ≥ 5.0 inches d.b.h. and ≥ 0.6 inch d.b.h

Weighting by $(D^2H)^{-2}$ provided greater improvement than did $(D^2H)^{-1}$ in 10 of 20 cases. $(D^2H)^{-1}$ was better in eight cases, while both weights were equally effective in two cases. However, differences between relative efficiencies of weighted regressions were 0.15 or less except for IB regressions based on trees ≥ 0.6 inch. In most cases the relative efficiencies for loblolly regressions were larger than those for shortleaf.

The relative efficiencies for shortleaf and loblolly total volume OB equations weighted by $(D^2H)^{-2}$ are smaller than those reported by Embry and Haack (1965) for western hemlock *(Tsuga heterophylla* (Ref.) Sarg.) and Sitka spruce *(Picea sitchensis* (Bong.) Carr.). The ranges in D and H for these two western species were much greater than those for the two southern pines, and weighting would be expected to result in larger efficiencies. The decrease in relative efficiencies with decrease in top utilization was also evident in Embry and Haack's data.

As might be expected from the relative efficiency values, actual reductions in standard errors in terms of volume were small—0.3 cubic foot or less in all categories. Untransformed standard errors (indices of fit) for shortleaf IB equations were consistently less than those for OB equations for all combinations of utilization level and weight. In contrast, the majority of errors for loblolly IB equations were greater than those for OB equations.

Untransformed standard errors for loblolly IB equations were consistently greater than the errors for respective shortleaf equations. The reverse was true in 12 of 15 cases for OB equations.

Since results of weighting by $(D^2H)^{-2}$ and $(D^2H)^{-1}$ were similar and the former was superior in more cases, all equations were weighted by $(D^2H)^{-2}$ for simplicity. A test of homogeneity of regression coefficients across physiographic provinces indicated no significant effects of province.

Intercept values for total utilization are close to zero (table 3). The slopes of OB equations

Table 2.—*Indices of fit (I) and relative efficiencies (RE) of three weights for volume on D^2H regressions* [1]

Utilization level	Statistical parameter	Weights					
		1		$(D^2H)^{-1}$		$(D^2H)^{-2}$	
		OB	IB	OB	IB	OB	IB
LOBLOLLY							
Trees ≥ 5.0 inches d.b.h.							
Total	I [2]	0.6434	0.7253	0.5035	0.5537	0.5167	0.5422
	RE [3]			1.28	1.31	1.24	1.34
2-inch top	I	.6470	.7254	.5081	.5540	.5237	.5438
	RE			1.27	1.31	1.24	1.33
3-inch top	I	.6621	.7289	.5340	.5632	.5673	.5646
	RE			1.24	1.29	1.17	1.29
4-inch top	I	.7132	.7437	.6078	.5950	.6722	.6208
	RE			1.17	1.25	1.06	1.20
Trees ≥ 0.6 inch d.b.h.							
Total	I	.4944	.5612	.2650	.2875	.2776	.2295
	RE			1.86	1.95	1.78	2.44
SHORTLEAF							
Trees ≥ 5.0 inches d.b.h.							
Total	I	.6174	.5805	.5260	.4692	.5228	.4476
	RE			1.17	1.24	1.18	1.30
2-inch top	I	.6223	.5825	.5310	.4706	.5285	.4492
	RE			1.17	1.24	1.18	1.30
3-inch top	I	.6476	.5928	.5613	.4838	.5682	.4683
	RE			1.15	1.22	1.14	1.26
4-inch top	I	.7135	.6238	.6356	.5204	.6617	.5181
	RE			1.12	1.20	1.08	1.20
Trees ≥ 0.6 inch d.b.h.							
Total	I	.4649	.4422	.2740	.2543	.2516	.2098
	RE			1.70	1.74	1.85	2.11

[1] Based on regressions for combined physiographic provinces.

[2] Index of fit. For a weight of unity $I = S_{y \cdot x}$; for weighted regressions I may be regarded as an average standard error transformed to units of volume.

[3] Relative efficiency. The ratio of $S_{y \cdot x}$ for the unweighted regression to the index of fit for a weighted regression.

Table 3.—*Summary of loblolly and shortleaf pine volume prediction equations for combined physiographic provinces*

Volume category	Loblolly		Shortleaf	
	Intercept	Slope	Intercept	Slope
	TREES ≥ 5.0 INCHES DBH			
VOBTOT	0.1683	0.0026109	−0.0326	0.0027379
VIBTOT	−.0709	.0020695	−.3052	.0021767
VOB2IN	.1034	.0026118	−.0913	.0027396
VIB2IN	−.1201	.0020702	−.3482	.0021782
VOB3IN	−.1051	.0026271	−.3085	.0027599
VIB3IN	−.2811	.0020821	−.5070	.0021914
VOB4IN	−.6054	.0026638	−.7722	.0027765
VIB4IN	−.6586	.0021059	−.8459	.0021966
	TREES ≥ 0.6 INCH DBH			
VOBTOT	.0236	.0027462	.0353	.0027771
VIBTOT	.0118	.0019989	.0088	.0019977

are close to 0.0027271, the constant in the paraboloid formulas (1) and (2) for obtaining individual bolt volumes. Measurements of DOB at breast height and H, and use of equation (1) would closely approximate results of the least squares fitting of the OB data. While most of the equations have a negative intercept, the intercept generally departs from the origin and the slope increases with increase in top diameter limit from 2 to 4 inches. The OB equations have a steeper slope in all cases than those for IB. As D^2H increases, volume increases at a faster rate OB than IB.

LITERATURE CITED

Embry, R. S., and Haack, P. M.
1965. Volume tables and equations for young-growth western hemlock and Sitka spruce in southeast Alaska. USDA For. Serv. Res. Note NOR-12, 21 p. North. For. Exp. Stn., Juneau, Alaska.

Fenneman, N. M.
1938. Physiography of Eastern United States. 714 p. N. Y.: McGraw-Hill.

Furnival, G. M.
1961. An index for comparing equations used in constructing volume tables. For. Sci. 7: 337-341.

Smalley, G. W., and Bower, D. R.
1968a. Volume tables and point-sampling factors for loblolly pines in plantations on abandoned fields in Tennessee, Alabama, and Georgia highlands. USDA For. Serv. Res. Pap. SO-32, 13 p. South. For. Exp. Stn., New Orleans, La.

Smalley, G. W., and Bower, D. R.
1968b. Volume tables and point-sampling factors for shortleaf pines in plantations on abandoned fields in Tennessee, Alabama, and Georgia highlands. USDA For. Serv. Res. Pap. SO-39, 13 p. South. For. Exp. Stn., New Orleans, La.

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VARIATION AMONG SHORTLEAF PINES IN A MISSISSIPPI SEED SOURCE PLANTING

O. O. Wells [1]

SOUTHERN FOREST EXPERIMENT STATION

Large differences in the traits related to growth rate were evident between trees from parts of the shortleaf range where the climate is mildest and those from areas of more severe climate. Specific gravity of extracted wood varied from 0.428 to 0.469, but no geographic pattern was evident. Time of growth initiation in the spring varied widely between populations east and west of the Mississippi River.

Additional keywords: Provenance, genecology, *Pinus echinata.*

Most genetic information about geographic variability in shortleaf pine *(Pinus echinata* Mill.) derives from the 40 plantings of the Southwide Pine Seed Source Study (Rogers and Phares, 1962; Little, 1969; Posey and McCullough, 1969; Wells and Wakeley, 1970). With few exceptions, only traits of obvious economic importance—height, diameter, volume, pest resistance—have been studied in the rangewide plantings of the Southwide Study. And although 15 geographic seed sources are represented, only six are under test at any one planting site. The present report describes results from a 9-year-old planting that includes all 15 of the Southwide Study shortleaf seed sources, plus one from northern Arkansas. The planting, which is in southern Mississippi, has been analyzed more intensively than most of those in the Southwide Study.

[1] The author is Principal Plant Geneticist at the Southern Forest Experiment Station, Gulfport, Mississippi.

METHODS AND MATERIALS

One-year-old stock from the 16 widely separated sources was grown from seed at the Harrison Experimental Forest, and was planted near Gulfport, Mississippi, in January 1958. The seed sources represent the major part of the species range; table 1 summarizes the climatic data.

The design was a randomized complete block with four blocks of 25-tree row plots. As the northern Arkansas seedlings were in short supply, three blocks contained only 12 seedlings of this source.

The site was cutover longleaf land with infertile, sandy soil; plantation spacing was 8 by 6 feet. Survival and juvenile growth were excellent throughout the study. Tip-moth injury was practically nil—an unusual situation for shortleaf in the area.

Table 1.—*Mean values for climatic variables at 16 shortleaf pine seed sources* [1]

Region and seed lot [2]	Annual temp.	Jan. min. temp.	Precipitation			Frost-free season
			Annual	Jan.-Apr.	June-Aug.	
	°F	°F	------ Inches ------			Days
South-central Pa., C-451	53.0	23.6	36.0	10.7	10.6	201
Southern N. J., C-453	54.1	29.1	41.8	14.0	11.5	209
Southeastern Va., C-455	60.7	32.4	43.2	13.3	14.3	199
Western S. C., C-457	63.2	34.1	46.7	16.3	13.4	221
Northern Ga. (Clarke County), C-461	60.2	33.3	53.7	20.5	14.0	213
Northern Ga. (Putnam County), C-463	62.7	34.8	49.9	19.7	12.6	217
Southwestern Ga., C-465	67.4	40.3	49.5	18.1	15.4	249
East-central Ala., C-467	65.2	39.1	52.8	21.6	13.8	237
Southeastern La., C-473	67.8	42.5	59.5	20.8	16.9	255
Eastern Tex., C-475	65.6	38.8	48.3	17.8	9.2	236
Southeastern Okla. (Pushmataha County), C-477A	61.8	32.0	54.0	18.5	12.6	227
Southeastern Okla. (McCurtain County), C-477B	61.8	32.0	54.0	18.5	12.6	227
Southeastern Ark., C-481	64.8	36.2	49.1	20.5	9.4	228
Northern Ark.	59.2	26.5	45.5	14.7	11.8	205
South-central Mo., C-485	55.9	23.4	43.8	13.4	11.6	182
Northeastern Tenn., C-487	59.3	31.1	45.5	17.7	11.6	217

[1] From Hocker (1955).
[2] Seed lot identification numbers are from the Southwide Pine Seed Source Study.

Survival and height were measured after 5 years. At age 9, height and d.b.h. of all trees were again measured and the stand was thinned. Thinning was done mainly by removing every other tree in each row. Some exceptions were necessary, however, because of failed spots and the desire to leave good trees in the residual stand. Competition was not intense at age 9, and many of the trees removed in each row were of comparable quality to those left. Of the trees removed in thinning, the five tallest were selected and the main stems, without branches, were weighed. A 6-inch segment was then cut from each of the five stems at a point 3 feet above groundline.

Finally, the number of trees that had begun growth was recorded on March 21 and 27, 1967, after the thinning. Growth initiation was determined for each tree by the presence or absence of green, succulent tissue exposed at the base of the terminal bud. Observations were made from a 15-foot-high wheeled platform towed behind a tractor.

In the laboratory, a ½-inch-thick disk was sawed from each 6-inch stem segment, the bark removed, and the disk cut in half. Extractives were removed from one half-disk by the method of White and Saucier (1966). Specific gravity was determined by the water displacement method and ovendry weight on both halves of the disk. Percentage of summerwood was measured, and tracheid length was determined on a sample taken from the fifth ring from the pith.

ANALYSES

Form was quantified by dividing total height by d.b.h. The plantation average was 5.6, and differences among seed sources were small and nonsignificant. Volumes per plot were calculated from average diameter, height, and survival—a conic tree form was assumed. The stem weight data were used to calculate "green weight per acre" and, together with the unextracted specific gravity, "dry weight per acre."

All simple correlations among traits were calculated, and multiple regressions were run with height, green weight per acre, flushing date, specific gravity, and tracheid length as dependent variables and six characteristics of the climate at seed source as independent variables. Plot means were the units of analysis in all cases. All data were subjected to analysis

of variance and multiple range tests at the 0.05 level of probability.

RESULTS AND CONCLUSIONS

Survival at age 5 was better than 90 percent for all sources, and there were no significant differences among sources. The correlation coefficient between fifth- and ninth-year heights was 0.92. As the variation among sources was more strongly expressed at the older age, only the ninth-year results will be presented here.

Large differences in growth rate were evident between trees from the parts of the shortleaf range where the climate is mildest and those from areas of more severe climate (table 2, fig. 1). The three fastest growing sources, Texas, Louisiana, and southwest Georgia, produced almost 2.5 times as much dry wood per acre at age 9 as the three slowest growing ones, New Jersey, Missouri, and Pennsylvania. The six climatic variables at seed source accounted for 76 percent of the variation in height and 62 percent of the variation in green weight per acre (table 3).

Among the trees from west of the Mississippi River (Texas, southeastern Arkansas, and Oklahoma), the relationship between growth and climate at seed source was somewhat better expressed in this planting than in the 10 plantings of the Southwide Study where trees of these same three origins are compared (Wells and Wakeley, 1970; fig. 6). The only obvious exception to the strong correlation with climate was the performance of northern Arkansas trees, which ranked high in all growth traits despite their northern origin. Probably their performance should be discounted somewhat, however, as they were represented in the planting by only about half as many trees as the others.

Differences in tracheid length among seed sources were small and nonsignificant. They averaged 2.7 mm. over all sources.

Specific gravity of extracted wood varied from 0.428 to 0.469 among the various sources; no geographic pattern was evident. There was no correlation with growth characters (table 4), a noteworthy result in that fast growth and low specific gravity are often thought to be associated. Taken singly by simple regression,

Table 2.—*Ninth-year performance in southern Mississippi of shortleaf pines from 16 sources*

Seed source [1]	Height	D.b.h.	Vol. per acre	Wt. of wood per acre		Wood specific gravity		Summer-wood	Mean date of pollen shed in Apr. 1969-70 [2]
				Green	Dry	Ex-tracted	Unex-tracted		
	Ft.	*In.*	*Cu. ft.*	*-- Tons --*				*Pct.*	
New Jersey, C-453 [2]	15.3	2.7	161	13.22	6.43	0.430	0.461	27.8	16.2
Pennsylvania, C-451	13.1	2.4	117	8.12	4.77	.451	.481	32.8	16.2
Virginia, C-455	18.0	3.2	280	17.33	10.19	.436	.465	30.0	16.2
Tennessee, C-487	18.3	3.1	283	17.56	10.02	.450	.477	30.1	15.2
Missouri, C-485	14.8	2.5	151	10.98	6.43	.434	.466	29.6	13.8
Northern Arkansas	18.8	3.6	389	22.22	13.67	.451	.481	32.0	13.8
South Carolina, C-457	18.6	3.2	316	17.25	10.41	.437	.468	27.1	16.8
Northeastern Georgia, C-461	19.0	3.3	336	18.51	11.16	.442	.471	28.5	15.9
Central Georgia, C-463	18.1	3.2	285	16.73	10.15	.428	.458	29.0	15.0
East-central Alabama, C-467	17.9	3.2	302	16.38	10.26	.431	.461	26.8	11.0
Southeastern Arkansas, C-481	19.2	3.4	351	19.45	12.36	.449	.481	30.4	12.0
Southeastern Oklahoma, C-477A	18.3	3.0	255	16.04	10.61	.469	.499	30.6	12.0
Southeastern Oklahoma, C-477B	17.7	3.2	296	18.38	12.13	.469	.503	33.0	13.8
Southwestern Georgia, C-465	20.3	3.6	439	22.25	14.46	.446	.476	28.8	14.0
Louisiana, C-473	19.2	3.4	353	20.60	13.30	.437	.469	27.7	13.9
Texas, C-475	20.2	3.6	420	21.85	14.59	.452	.485	29.2	12.2
Tukey's L.S.D.	2.8	.4	91	7.37	3.56	.037	.036	5.6	..

[1] Seed lot identification numbers are from the Southwide Pine Seed Source Study.
[2] Schmidtling (1971).

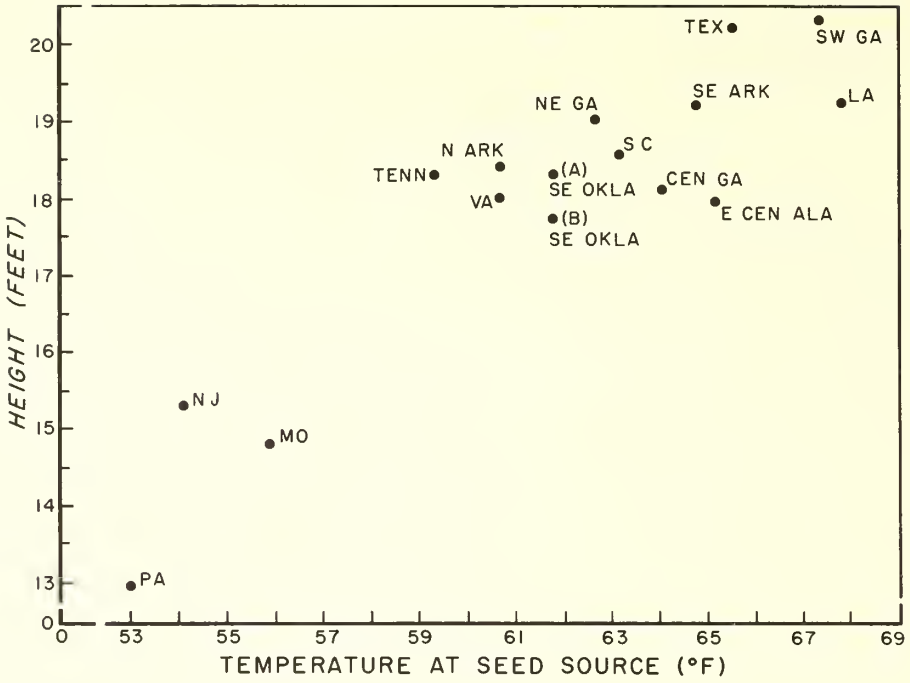

Figure 1.—*Nine-year height and mean annual temperature at seed source.*

Table 3.—*Proportion of variation (r^2) in five traits accounted for by climatic variables at seed source*

Trait	Climatic variable at seed source						All climatic variables
	Annual temp.	Jan. min. temp.	Annual precipitation	Jan.-Apr. precipitation	June-Aug. precipitation	Frost-free season	
	Percent						
Height	0.74*	0.60*	0.43*	0.49*	0.08	0.46*	0.76*
Green weight per acre	.60*	.46*	.34*	.33*	.07	.40*	.62*
Growth initiation	.41*	.29*	.22	.23	.09	.33*	.97*
Specific gravity	.00	.01	.04	.00	.08	.08	.74*
Tracheid length	.03	.04	.01	.00	.03	.04	.22

* "r" significant at 0.05 percent level.

Table 4.—*Simple correlation coefficients (r) among traits*[1]

Trait	Ht.	D.b.h.	Vol. per acre	Green wt. per acre	Dry wt. per acre	Sp. gr. (ext.)	Sp. gr. (unext.)	Tracheid length	Percent of summerwood	Form
D.b.h.	0.95									
Volume per acre	.95	0.98								
Green weight per acre	.95	.98	0.98							
Dry weight per acre	.94	.97	1.00	0.98						
Specific gravity extracted	.18	.16	.12	.22	0.31					
Specific gravity unextracted	.17	.14	.18	.22	.36	0.99				
Tracheid length	−.12	−.14	−.12	−.09	−.11	−.01	−0.01			
Percent of summerwood	−.31	−.17	−.16	−.14	−.06	.71	.70	0.20		
Form	.14	−.12	−.11	−.03	−.04	.23	.19	.39	−0.12	
Growth initiation	.56	.54	.62	.54	.65	.44	.51	−.10	.08	0.19

[1] Values equal to or greater than 0.50 are significant at the 0.05 level.

none of the six climatic variables accounted for more than a negligible amount of variation in specific gravity, but together, in a multiple regression equation, each contributed substantially and explained 74 percent of the variation (table 3). This result contrasts with that for the growth traits, where several of the climatic variables, particularly mean annual temperature, individually explained much of the variation in height, green weight per acre, and growth initiation. The biological relationships underlying these two types of association (single vs. multiple effects) are not even clear enough to support speculation.

Posey and McCullough (1969) tested some of the same seedlots on two sites in southeastern Oklahoma and found the southeastern Arkansas trees to have the densest wood and longest tracheids, and to be the fastest growing. In the Mississippi planting the southeastern Arkansas trees ranked high in all these traits but excelled in none of them. Further, they did not excel in growth rate in several other Southwide Study plantings, including two in southern Arkansas where the climate is similar to that of southeastern Oklahoma (Wells and Wakeley, 1970).

These differences between results in the Oklahoma, Mississippi, and other Southwide Study plantings are difficult to reconcile. Perhaps they represent random fluctuations around some mean performance. Alternatively, the slightly different environment in southeastern Oklahoma may in some way favor the southeastern Arkansas source over others.

In the present study, time of growth initiation in the spring provides a striking contrast between the shortleaf populations east and west of the Mississippi River (fig. 2). Despite the gap in the sampling in Mississippi and most of Alabama, it appears that the Mississippi River is the dividing line and that the southeastern Louisiana trees represent the extremity of a NE-SW oriented cline that extends throughout the eastern population. The affinity of the southeastern Louisiana trees to the eastern population is most evident when the relationship between mean annual temperature

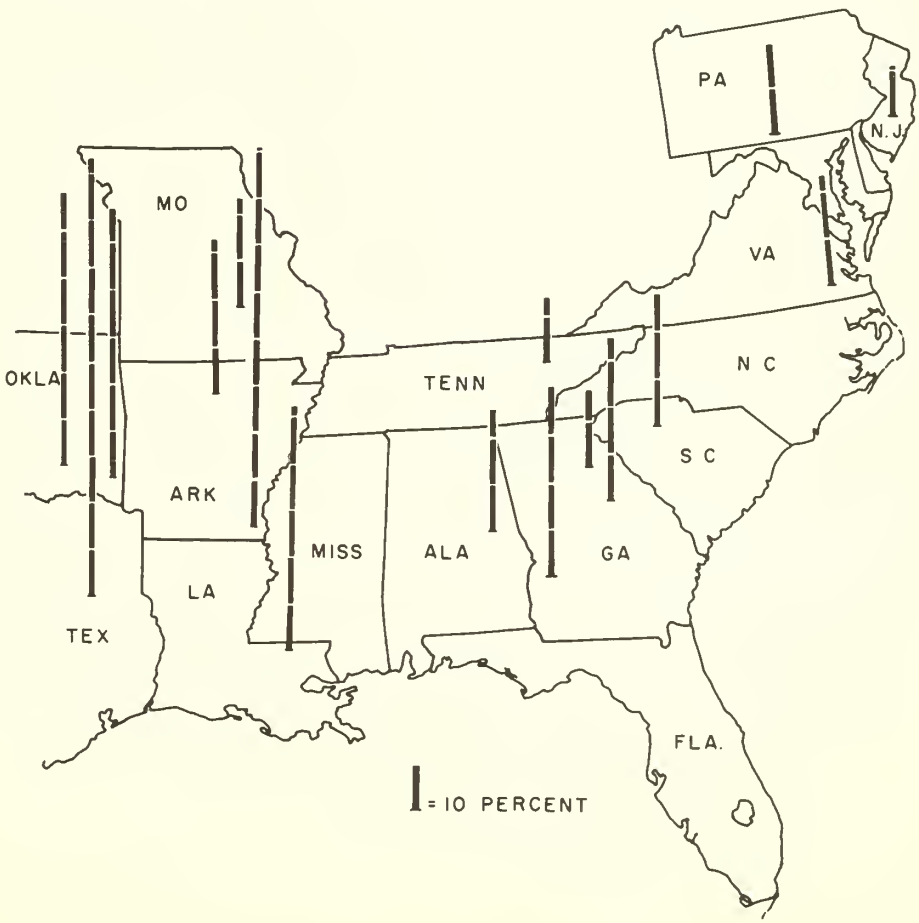

Figure 2.—
Percent of trees that had begun growth on March 21, 1967. Shortleaf pines from 16 seed sources growing in southern Mississippi.

at seed source and time of growth initiation in the southern Mississippi planting is considered (fig. 3). The Mississippi River provides effective reproductive isolation, as it and its floodplain are an essentially pineless barrier from 25 to 120 miles wide.

Schmidtling (1971) observed time of pollen shed in the same plantation in 1969 and 1970. When his data are compared with mine, it appears that 45 percent of the variation in pollen shed time could be explained by differences in onset of vegetative growth. This is substantial, considering that different methods of measurement were used (mean time of pollen shed vs. proportion of trees growing at a specific time) and that the measurements were taken in different years. Thus, there is a fair correlation between vegetative and reproductive phenology in this provenance planting.

The difference in time between the early and late flushing sources, while distinct, is only a few days. When the planting was reassessed 1 week after the initial observation, practically all trees were actively growing. Therefore, differences in the onset of growth in the spring do not appear to be primarily responsible for differences in growth rate among the seed sources, even though one accounts for about one-third of the variation in the other (table 4). On the basis of Roche's (1970) work, time of growth cessation in the fall might be expected to show a stronger correlation with total growth than does time of flushing.

It is noteworthy that differences in onset of growth are the only consistent indication of genetic differences between the shortleaf populations east and west of the Mississippi River. None of the other traits show this discontinuity for seed sources of comparable latitude. However, rate of growth and characteristics of wood are not generally considered to be good diagnostic traits. Growth initiation may well be a better indicator of genetic distinctness. There is considerable evidence that the loblolly pine population west of the Mississippi River is genetically distinct from the population east of the River (Wells and Wakeley, 1966; Wells and Switzer, 1971) and that this distinctness is due to introgression with shortleaf pine (Hare and Switzer, 1969). Presumably, the introgression west of the Mississippi River has had some effect on the shortleaf population there as well. If this assumption is true it may explain the difference in growth initiation.

The study provides an opportunity to compare the potential genetic gain in dry weight of wood per acre if seed sources are selected solely on the basis of growth rate or solely on

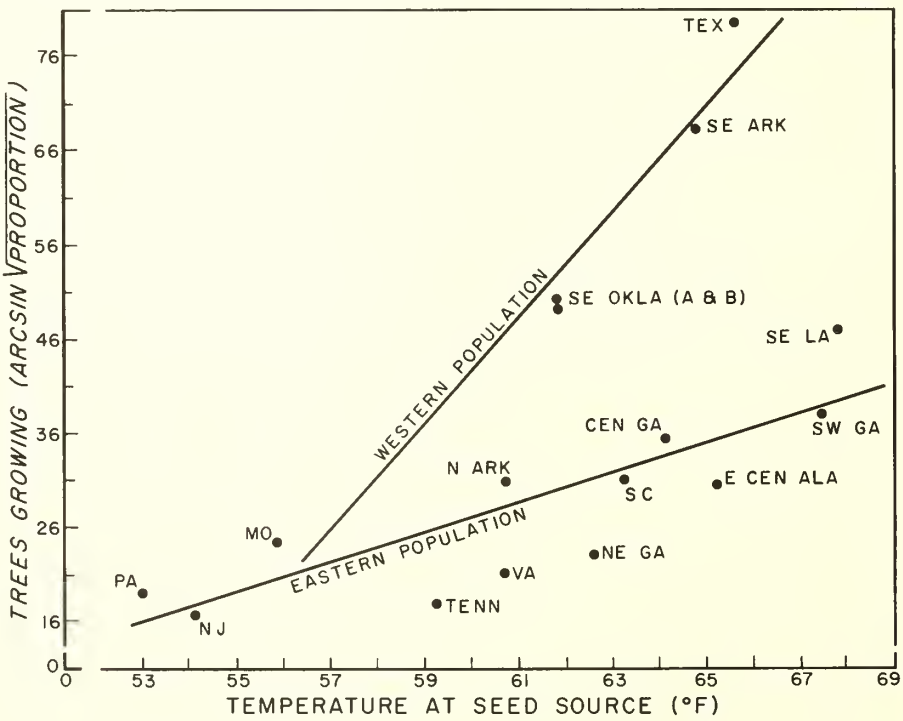

Figure 3.—
Proportion of trees actively growing on March 21, 1967, and mean annual temperature at seed source.

the basis of wood specific gravity. The range in specific gravity (0.503 to 0.458) would correspond to a difference of slightly less than 1 ton of dry wood per acre if calculated at the volume of the average seed-source plot. On the other hand, the range in volume (972 to 318 cubic feet) would correspond to a difference of nearly 10 tons of dry wood per acre at the specific gravity of the average seed-source plot. Clearly, seed sources should be chosen on the basis of volume rather than specific gravity.

Geographic patterns of variability in wood specific gravity have been studied in most species of southern pine. Wood samples have been taken both in place throughout the range of the species and in seed-source plantings where trees of various origins are growing in a common environment. Substantial work in place has shown conclusively that wood specific gravity varies geographically in a predictable manner. More particularly, density in slash, loblolly, shortleaf, and longleaf pine increases from the northwestern to the southeastern part of the species' distribution (Larson, 1957; Goddard and Strickland, 1962; Zobel et al., 1960; Mitchell, 1964).

The pattern of variation in seed source plantings, however, does not agree with the pattern established in place. Either variation has occurred at random over the distribution of the species, as in the present study, or density has actually been lowest among the trees originating farthest to the southeast (Thor and Brown, 1962; Gilmore et al., 1966; Jackson and Strickland, 1962; Saucier and Taras, 1966; White and Saucier, 1966; Lantz and Hofmann, 1969).

This is strong evidence that the pattern of geographic variability found in the tests in place is attributable largely to environment, probably mostly climate, and is not inherent. Because of this and the fact that genetic variation in volume is several times greater in terms of dry weight of wood per unit than is the case for specific gravity, it seems that efforts made to utilize the genetic portion of the geographic variability in wood specific gravity would not be practical. There is substantial genetic variation among individual trees in a given locality, however, and the chances of utilizing this for genetic gain look very promising (Zobel et al., 1972).

LITERATURE CITED

Gilmore, A. R., Boyce, S. G., and Ryker, R. A.
1966. The relationship of specific gravity of loblolly pine to environmental factors in southern Illinois. For. Sci. 12: 399-405.

Goddard, R. E., and Strickland, R. K.
1962. Geographic variation in wood specific gravity of slash pine. TAPPI 45: 606-608.

Hare, R. C., and Switzer, G. L.
1969. Introgression with shortleaf pine may explain rust resistance in western loblolly pine. USDA For. Serv. Res. Note SO-88, 2 p. South. For. Exp. Stn., New Orleans, La.

Hocker, W. H., Jr.
1955. Climatological summaries for selected stations in and near the southern pine region, 1921-1950. USDA For. Serv. Southeast. For. Exp. Stn., Stn. Pap. 56, 11 p.

Jackson, L. W. R., and Strickland, R. K.
1962. Geographic variation in tracheid length and wood density of loblolly pine. Ga. For. Res. Counc. Pap. 8, 4 p.

Lantz, C. W., and Hofmann, J. G.
1969. Geographic variation in growth and wood quality of loblolly pine in North Carolina. Tenth South. For. Tree Improv. Conf. Proc., p. 175-188.

Larson, P. R.
1957. Effect of environment on the percentage of summerwood and specific gravity of slash pine. Yale Univ. Sch. For. Bull. 63, 78 p.

Little, S.
1969. Local seed sources. USDA For. Serv. Res. Pap. NE-134, 16 p. Northeast. For. Exp. Stn., Upper Darby, Pa.

Mitchell, H. S.
1964. Patterns of variation in specific gravity of southern pines and other coniferous species. TAPPI 47: 276-283.

Posey, C. E., and McCullough, R. B.
1969. Tenth year results of a shortleaf pine seed source study in Oklahoma. Okla. Agric. Exp. Stn. Bull. B-668, 14 p.

Roche, L.
1970. The silvicultural significance of geographic variation in the white Engelmann spruce complex in British Columbia. For. Chron. 46: 116-125.

Rogers, N. F., and Phares, R. E.
1962. Northern seed sources best for shortleaf pine plantings in Missouri. USDA For. Serv. Cent. States For. Exp. Stn., Stn. Note 155, 2 p.

Saucier, J. R., and Taras, M. A.
1966. Wood density variation among six longleaf pine seed sources grown in Virginia. J. For. 64: 463-465.

Schmidtling, R. C.
1971. Geographic races of shortleaf pine not reproductively isolated in a mixed plantation. Eleventh South. For. Tree Improv. Conf. Proc., p. 212-217.

Thor, E., and Brown, S. J.
1962. Variation among six loblolly pine provenances tested in Tennessee. J. For. 60: 476-480.

Wells, O. O., and Switzer, G. L.
1971. Variation in rust resistance in Mississippi loblolly pine. Eleventh South. For. Tree Improv. Conf. Proc., p. 25-30.

Wells, O. O., and Wakeley, P. C.
1966. Geographic variation in survival, growth, and fusiform-rust infection of planted loblolly pine. For. Sci. Monogr. 11, 40 p.

Wells, O. O., and Wakeley, P. C.
1970. Variation in shortleaf pine from several geographic sources. For. Sci. 16: 415-423.

White, J. F., and Saucier, J. R.
1966. A comparison of the specific gravity of two slash pine varieties grown in south Florida. TAPPI 49: 230-232.

Zobel, B. J., Kellison, R. C., Matthias, M. F., and Hatcher, A. V.
1972. Wood density of the southern pines. N. C. Agric. Exp. Stn. Tech. Bull. 208, 56 p.

Zobel, B. J., Thorbjornsen, E., and Henson, F.
1960. Geographic, site, and individual tree variation in wood properties of loblolly pine. Silvae Genet. 9: 149-158.

SOUTHERN FOREST EXPERIMENT STATION

1973

U.S. FOREST SERVICE RESEARCH NOTE

SO-163

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

DECLINING PINES ASSOCIATED WITH BARK BEETLE ACTIVITY IN ALLEN PARISH, LA.

Peter L. Lorio, Jr. [1]

SOUTHERN FOREST EXPERIMENT STATION

From June 1969 through November 1971, southern pine beetle (Dendroctonus frontalis *Zimm.) activity was found on five of 100 0.1-acre plots that contained declining trees. A total of 74 infestations occurred within a 5-chain radius of the plots, and 46 plots had at least one infestation within 5 chains of plot center.* Ips *activity was rare, but black turpentine beetle attacks* (D. terebrans *(Olivier)) were noted on 33 of the plots.*

Additional keywords: *Dendroctonus frontalis, D. terebrans, Ips* spp., *Pinus taeda.*

Recurring bark beetle outbreaks may be fostered by declining loblolly pines *(Pinus taeda* L.), which are common in stands 40 or more years old on poorly drained sites (Lorio, 1966). Because these trees have thin, yellowish crowns, poor root systems, and low oleoresin reservoirs, they do not react to bark beetle attack as do apparently healthy trees. Their crowns fade very slowly, and pitch tubes are either absent or unusually small. Often conclusive evidence of southern pine beetle *(Dendroctonus frontalis* Zimm.) attack can only be obtained by close examination of the midbole of an affected tree.

This paper describes infestations occurring on a sample of declining pines in a chronic bark beetle problem area. Southern pine beetle (SPB), black turpentine beetle (BTB) *(D. terebrans* (Olivier)), and *Ips* species activity was noted.

MATERIALS AND METHODS

The study area included pure pine and pine-hardwood forests belonging to the Southwestern Improvement Company and located near Oakdale, La. One hundred blocks of 40 acres each were randomly selected for observation and then thoroughly searched for declining pines. In most blocks a 0.1-acre circular plot was established with a severely declining pine as its center; these central trees served as primary study trees. Thirty plots were in areas where severely affected trees were scarce; here the primary study trees were in moderate to severe decline. On six plots trees that had apparently succumbed to SPB attacks were used as plot centers, and nearby declining trees

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within the plots were the primary study trees. During the study two complete plots and one primary tree were lost through logging.

Declining trees were identified by crown characteristics. All had abnormally short, yellowish needles, sparse crowns, and ascending branches. Some had dying branches. Many crowns appeared tufted because of reduced needle retention or shortened internodes on the leaders; some had an abundance of cones.

Total height, live crown length, d.b.h., and increment cores at breast height were obtained for all primary study trees. Increment cores and d.b.h. were also taken on other dominant and codominant pines on the plots. Cores were stored in 4 percent formalin, and annual growth over the last 10 years was later determined by microscopic measurement of annual rings.

Primary study trees averaged 42.7 cm (16.8 in) in diameter, 27 m (89 ft) in height, 0.36 in live crown ratio, and 24.3 mm (0.96 in) in radial growth. Data for all trees on the plots are given in table 1. About 90 percent of the trees were classed as moderately or severely declining, and their average radial growth was only 25.9 mm in 10 years. Trees classed as healthy grew 35.0 mm in 10 years.

Table 1.—*Average diameter, and 10-year radial growth of dominant and codominant plot trees in three vigor classes*

Vigor class	D.b.h.	Radial growth	Number of trees
	Cm	*Mm*	
Healthy	41.4	35.0	44
Moderate decline	38.6	26.6	304
Severe decline	42.4	23.9	99
All classes	39.6	26.8	447

The 100 plots were established between January and June of 1969. In four subsequent inspections (June-Sept. 1969, March-May 1970, Oct. 1970-Jan. 1971, and Aug.-Nov. 1971), trees on the plots were closely examined for SPB, BTB, and *Ips* activity. The area within 5 chains of each plot center was also searched for SPB-infested trees. The area examined around each point was about 8 acres per plot, and the overall sampling density was close to 3 percent of the pine and pine-hardwood sawtimber area.

Just prior to and during the establishment of the study plots, the level of SPB activity was very low. Surveys of Allen Parish made in October 1968 and March 1969 indicated approximately 2 to 4 infested trees per thousand acres of host type. Another survey in July 1969 revealed the lowest infestation level "since the discovery of southern pine beetle in Allen Parish in October 1963."[2]

RESULTS AND DISCUSSION

SPB infestations occurred on five of the plots, and a total of 74 infestations were found within a 5-chain radius of the plots (table 2). All five plots with SPB-infested trees were in pure pine. Two other plots contained active SPB infestations when the study began, but the beetles were controlled or the trees salvaged shortly after plot establishment. No further activity was found on the two plots, although one later had two SPB infestations within a 4-chain radius.

Table 2.—*Frequency of southern pine beetle infestations on or near plots*

Inspection period	On 0.1-acre plot	Distance from plot center, chains					Total
		0-1	1-2	2-3	3-4	4-5	
June-Sept. 1969	1	3	6	2	0	0	11
Mar.-May 1970	1	8	2	4	3	0	17
Oct. 1970-Jan. 1971	0	4	3	2	3	0	12
Aug.-Nov. 1971	3	7	9	8	5	5	34
Total	5	22	20	16	11	5	74

By the end of November 1971, 46 plots had one or more SPB-infested trees within a 5-chain radius (table 3). The number of infestations and the number of plots associated with infestations had nearly doubled since the inspection in May 1970. Infestations were also becoming more common at greater distances

[2] Unpublished reports on file in the Division of Forest Pest Management Field Office, Pineville, La.

Table 3.—*Cumulative number of plots with one or more SPB-infested trees on or within specified radii of plots*

Inspection period	On 0.1-acre plot	Radius, chains				
		0-1	0-2	0-3	0-4	0-5
June-Sept. 1969	1	4	10	10	10	10
Mar.-May 1970	2	12	18	21	24	24
Oct. 1970-Jan. 1971	2	15	22	26	29	29
Aug.-Nov. 1971	5	21	33	40	42	46

from plot centers. The first two inspections following plot establishment revealed a higher incidence of SPB-infested trees within 2 chains than within 3 to 5 chains of the plots. The last inspection indicated that almost half the infestations were between 2 and 5 chains from the primary study trees (table 2).

During this same period the Louisiana Forestry Commission noted a marked increase in SPB activity throughout the area.[3] Its November 1971 survey indicated at least 49 infestations with an average of 34 trees each. The two largest infestations were estimated at 600 trees and 300 trees, both much larger than any occurring during a previous 5-year period of intensive control (Lorio and Bennett, 1973).

Ips species (*I. avulsus*, *I. grandicollis*, or *I. calligraphus*) were found on only six plots; four of these plots also had SPB and BTB activity.

Thirty-three plots contained one or more BTB infested trees; 24 of these had no evidence of other bark beetles, and four were associated with wounds made during previous inspections. The area has a history of frequent BTB attacks (Lorio and Bennett, 1973), and it seems likely that BTB activity contributes indirectly to the more devastating SPB outbreaks. BTB infestations weaken trees and thus make them more susceptible to attack by other beetles.

The role of declining trees in bark beetle ecology can not be conclusively defined on the basis of this study alone. However, these findings lend credence to the theory that declining trees are important in the maintenance of SPB populations during endemic periods. Organisms may survive unfavorable periods in a part of the environment very unlike that which permits general population increase (Henson, 1962). It appears that a small number of beetles can attack declining trees successfully and produce brood sufficient to maintain endemic populations.

Other researchers found that attacking SPB produce an aggregating pheromone that leads to mass attack only as long as the host resists extensive feeding and gallery construction (Vité and Pitman, 1968; Vite and Crozier, 1968). They also noted that host attractiveness following initial attack is strongly influenced by its physiological condition, e.g. water balance and oleoresin reservoirs. Since declining trees have abnormal water balance and low oleoresin reservoirs, they offer little physical resistance to beetle attack. Presumably, pheromone production is limited, and the potential for mass attack is low. Commonly, infestations among declining trees occur as scattered single trees with only a portion of the bole attacked by SPB; and often BTB are found in the lower bole.

[3] Personal communication from B. F. Griffin, District Forester, La. For. Comm., Oberlin, La.

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LITERATURE CITED

Henson, W. R.
1962. Weather and insect epidemics. Fifth World For. Cong. Proc. Vol. 2, Sect. III. For. Prot., p. 847-851.

Lorio, P. L., Jr.
1966. *Phytophthora cinnamomi* and *Pythium* species associated with loblolly pine decline in Louisiana. Plant Dis. Rep. 50: 596-597.

Lorio, P. L., Jr., and Bennett, W. H.
1974. A five-year case history of recurring southern pine beetle infestations in Allen Parish, Louisiana. USDA For. Serv. Res. Pap. (in press). South. For. Exp. Stn., New Orleans, La.

Vité, J. P., and Crozier, R. G.
1968. Studies on the attack behavior of the southern pine beetle. IV. Influence of host condition on aggregation pattern. Contrib. Boyce Thompson Inst. 24: 87-94.

Vité, J. P., and Pitman, G. B.
1968. Bark beetle aggregation: effects of feeding on the release of pheromones in *Dendroctonus* and *Ips*. Nature 218: 169-170.

SOUTHERN FOREST EXPERIMENT STATION

1973

U.S. FOREST SERVICE RESEARCH NOTE

SO-164

Forest Service, U.S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

MISSISSIPPI COTTONWOODS OUTPERFORM LOCAL CLONES NEAR CAIRO, ILLINOIS [1]

W. K. Randall [2]

SOUTHERN FOREST EXPERIMENT STATION

In plantings near Cairo, Illinois, cottonwood clones from west-central Mississippi were taller and had larger diameters at age 5 than 22 local clones. The expected genetic gain from planting the four best clones would be 21 percent in diameter and 9 percent in height growth.

Additional keywords: *Populus deltoides*, clones, provenance, tree improvement.

Cottonwoods *(Populus deltoides* Bartr.) are growing faster than ever before in the lower Mississippi Valley, thanks to intensive culture and early results of tree improvement programs. The study described here was designed to learn whether geographic source of clones affects performance in the northern part of the lower Mississippi Valley, which runs south from Cairo, Illinois.

[1] A. J. Erwin Miller and Robert Hedden of Armstrong Cork Company supplied clones for this study from lands near Cairo, Illinois.

[2] The author is an Associate Silviculturist at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Mississippi, by the Southern Forest Experiment Station, USDA Forest Service, in cooperation with the Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group.

MATERIALS AND METHODS

Fifty clones were tested; 22 were from western Kentucky (designated Armstrong) and 23 from near Stoneville, 240 miles to the south. The Armstrong group was selected solely on the basis of phenotypic superiority in growth and form in a natural population near Wickliffe, Kentucky. The Stoneville clones are from seedlings of phenotypically selected female trees within 50 miles of Stoneville. Seedlings were selected for superior growth and form after two growing seasons in a one-parent progeny test. Of the remaining five clones, two are from a sandbar in west-central Mississippi (designated Rosedale), one each is from northeastern Texas, southeastern Arkansas, and east-central Illinois. The last three were selected for outstanding growth and form in natural stands.

No Stoneville clone released for commercial planting was included in the study, but several of those tested are half-sibs of the released clones.

All clones were grown for at least 1 year prior to field planting in the Armstrong Cork

Company nursery at Wickliffe, Kentucky. Twenty-inch unrooted cuttings from 1-year-old switches were planted. The first-year cultural practices recommended by McKnight (1970) were followed.

At each of three locations, four replications of 2-ramet plots were planted in randomized complete blocks. Spacing was 12×12 feet. Clones within sources were not grouped. A site near Wickliffe in Ballard County, Kentucky, was planted in the spring of 1965, and one near Morrison in Hickman County, Kentucky, was planted in the spring of 1966. Both plantings contained the same 50 clones. The third location, Conran in New Madrid County, Missouri, was established in 1967. It also contained 50 clones, but only 32 of them were common to the other two plantings.

All test locations are near the Mississippi River, and the distance between the northern- and southern-most plantings is 30 miles. Over these three sites, cottonwood site-index at age 30 ranged from 95 at Wickliffe to 120 at Morrison.

Heights were measured at Wickliffe after 1, 2, 3, and 5 years, and diameters after 3 and 5. At Morrison, heights were measured at ages 1 and 2, and diameters at 2 and 4. Height measurements at the Conran site were made at ages 1 and 3 years, and diameters at age 3.

Heights were taken to the nearest 0.1 foot, and d.b.h. to the nearest 0.1 inch. In the fall of 1969, each plantation was thinned by removing every other row, reducing each plot to a single ramet. At that time the Wickliffe, Morrison, and Conran plantings were 5, 4, and 3 years old, respectively.

Means were compared by analysis of variance, and all tests of significance were at the 0.05 level. For the last set of measurements, data were combined over sites for the 32 clones common to all locations.

RESULTS AND DISCUSSION

At all ages, the Stoneville (southern) population had a larger diameter than the Armstrong (local) population (table 1). When clone means were ranked at each site and over sites, the largest clones were from the southern population (table 2).

First-year height differences between the two populations were small, with northern sources taller at Morrison and Conran (table 1). Thereafter, the southern population was the tallest, and the difference between the two populations increased with age.

Table 1.—*Mean height and diameter of two cottonwood populations at three sites*

Site and population	Mean population height at age (years)				Mean population diameter at age (years)			
	1	2	3	5	2	3	4	5
	Feet				*Inches*			
Wickliffe								
Armstrong (local)	5.9	11.9	18.9	26.5	..	2.1	..	3.0
Stoneville (southern)	6.3	13.4	22.6	31.6	..	2.9	..	4.3
Morrison								
Armstrong (local)	9.2	20.8	.	.	2.2	..	5.1	.
Stoneville (southern)	8.2	21.3	.	..	2.5	..	5.7	..
Conran								
Armstrong (local)	8.1	.	23.4	.	.	2.5	.	.
Stoneville (southern)	7.4	.	24.8	.	.	3.0	..	..

The single clones from east-central Illinois was not included in the combined analysis because of several missing plots. It was, however, approximately average for height but less than average in diameter growth.

At all times of measurement, clones differed significantly in height and diameter. In the final diameter measurement, there were significant differences among clones, both within and between populations. When data were combined over locations, differences were significant for sites, clones, and clones within populations. Even though there were significant differences between mean diameters of the two populations at each location, when combined over locations a difference of 0.66 inch (4.25 vs. 3.59) was not statistically significant. Significant interactions occurred for clone × site, clones within each population × site, and population × site.

If all clones were planted on a broad range of sites represented by these three test locations, the best four clones should yield an expected genetic gain of 21 percent in diameter over the test mean. Genetic gain for height growth would be 9 percent over the mean height of all clones.

Table 2.—*Rank of 32 clones for diameter combined over three sites and for individual sites*

Clone number	Mean diameter	Combined rating	Wickliffe, age 5	Morrison, age 4	Conran, age 3
	Inches	----- *Rank* -----			
Stoneville-148	4.93	1	2	1	3
Texas-1	4.87	2	1	5.5	2
Stoneville-147	4.75	3	3	3	5.5
Stoneville-159	4.59	4	5	5.5	5.5
Stoneville-163	4.53	5.5	6	10.5	1
Rosedale-7	4.53	5.5	8	2	8
Rosedale-8	4.39	7	11	4	9
Armstrong-1	4.17	8	9.5	8	17
Armstrong-18	4.13	9	15.5	7	16
Stoneville-157	4.08	10	4	26	13
Armstrong-12	4.05	11	12	14.5	12
Armstrong-25	3.96	12	19.5	9	10.5
Stoneville-160	3.93	13	13	10.5	20.5
Stoneville-153	3.91	14	7	24	20.5
Armstrong-6	3.83	15	17.5	23	5.5
Stoneville-144	3.75	16	14	32	5.5
Armstrong-4	3.71	17	17.5	21	15
Armstrong-2	3.70	18	19.5	14.5	22.5
Armstrong-10	3.69	19	15.5	13	28.5
Arkansas-1	3.68	20	9.5	22	31
Armstrong-7	3.65	21	24	17	19
Armstrong-11	3.64	22	21	27	14
Armstrong-8	3.55	23	25	20	22.5
Armstrong-14	3.53	24	29	12	18
Armstrong-5	3.50	25	26	19	24
Armstrong-23	3.49	26	23	25	25
Stoneville-154	3.33	27	22	31	27
Armstrong-9	3.25	28.5	27	16	32
Armstrong-19	3.25	28.5	31	29	10.5
Armstrong-27	3.06	30.5	28	28	30
Armstrong-13	3.06	30.5	32	18	28.5
Armstrong-17	3.00	32	30	30	26

Stoneville clones had undergone two stages of selection prior to this test. First, desirable phenotypes were selected in natural stands; then the best seedlings were selected from a progeny test at age 2 years. The northern population had undergone only phenotypic selection in natural stands. The difference in growth between the two populations may in part be attributed to the additional selection within the southern population. However, a sizable proportion of the difference probably is due to the common phenomenon of southern sources growing faster than northern sources in a northern environment (Bey et al., 1971; Wells and Wakeley, 1966; and Pauley and Perry, 1954). Mohn and Pauley (1969) reported good performance of cottonwood moved north from Missouri to Minnesota.

In each of the three plantings near Cairo, Illinois, the clones from Stoneville, Mississippi, were taller and had larger diameters than local clones. Weather conditions during the 5 years of this study did not limit growth of Stoneville cottonwood when moved northward 240 miles.

LITERATURE CITED

Bey, C. F., Toliver, J. R., and Roth, P. L.
1971. Early growth of black walnut trees from twenty seed sources. USDA For. Serv. Res. Note NC-105, 4 p. Northeast. For. Exp. Stn., Upper Darby, Pa.

McKnight, J. S.
1970. Planting cottonwood cuttings for timber production in the South. USDA For. Serv. Res. Pap. SO-60, 17 p. South. For. Exp. Stn., New Oleans, La.

Mohn, C. A., and Pauley, S. S.
1969. Early performance of cottonwood seed sources in Minnesota. Univ. Minn. For. Res. Notes 207, 4 p.

Pauley, S. S., and Perry, T. O.
1954. Ecotypic variation of the photoperiodic response in Populus. J. Arnold Arboretum 35: 167-188.

Wells, O. O., and Wakeley, P. C.
1966. Geographic variation in survival, growth, and fusiform-rust infection of planted loblolly pine. For. Sci. Monogr. 11, 40 p.

SOUTHERN FOREST EXPERIMENT STATION

1973

U.S. FOREST SERVICE RESEARCH NOTE

SO-165

Forest Service, U.S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

APPLICATOR FOR GRANULAR SYSTEMIC INSECTICIDES IN COTTONWOOD NURSERIES AND PLANTATIONS

L. P. Abrahamson, L. Newsome, and T. P. Bouler [1]

SOUTHERN FOREST EXPERIMENT STATION

FEB 25 19

The applicator provides safe and effective placement of insecticides in the soil to depths of 18 inches. It resists damage by stumps and roots in newly cleared land, and is adapted to commercial operations.

Subsoil applications of granular insecticides are often required in nurseries or young plantations of eastern cottonwood. Most cottonwood sites are on newly cleared land containing numerous stumps and large roots. The applicator must therefore be heavy and strong enough to withstand rough use. On sandy loams considered suitable for cottonwood, trees are usually established by preparing cuttings 20 inches long and setting them in the soil to a depth of about 18 inches. Roots develop over nearly the full length of underground stem. To provide a safe and effective means for protecting young stands, we designed an applicator that could be operated up to 18 inches deep in the soil, would not be damaged in newly cleared land, and would be adaptable to commercial operations in both nurseries and plantations.

The applicator was developed to work off the 3-point hitch of a 75-horsepower tractor (fig. 1). The blades are of "T-1" (USS) [2] steel measuring 28 by 8 by 1 inches. The front edges were cut to V-shape. Each blade was welded to a 12- by 8- by 1-inch steel plate, and two steel braces, 4½ by 5¾ by ½ inch, were welded at a 45° angle between the blade and plate. A 1-inch (o.d.) galvanized pipe 24 inches long was welded to the back of the blade 2 inches from the bottom. The top of the pipe was bent to fit the hose angle from an electric insecticide dispenser. Two shields 4 by 4½ by ⅜ inches were welded on the lower back side of each blade to prevent soil from plugging the pipe opening.

[1] When the applicator was developed, Abrahamson was Entomologist at the Southern Hardwoods Laboratory, USDA Forest Service, Stoneville, Mississippi. He is now with the Southeastern Area Office of State and Private Forestry, USDA Forest Service, Atlanta, Ga. Newsome is Biological Technician and Bouler is Research Technician at the Laboratory, which is maintained by the Southern Forest Experiment Station in cooperation with the Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group.

[2] Mention of a proprietary product does not constitute a recommendation by the U. S. Department of Agriculture.

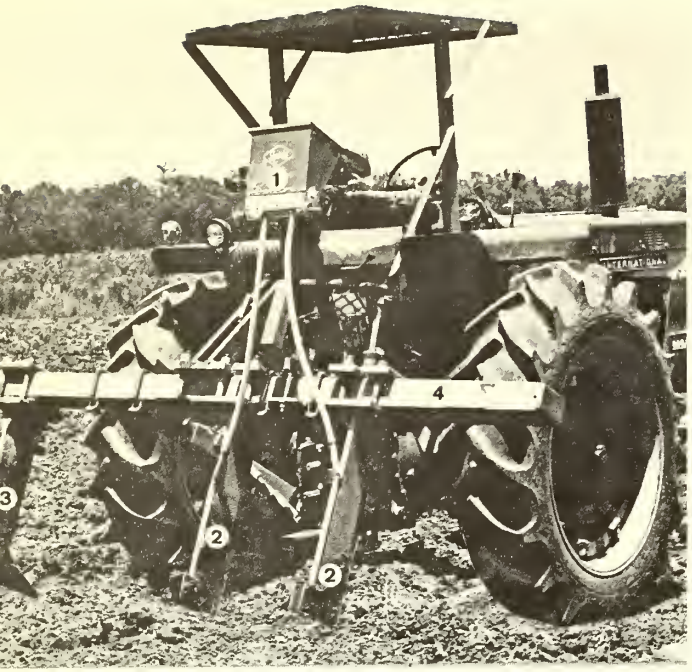

Figure 1.—*The applicator mounted on the 3-point hitch of a 75-horsepower tractor. The device consists basically of (1) an electric insecticide dispenser; (2) two heavy subsoil blades in back of which the granules are dropped; (3) a stabilizing blade, all mounted on a heavy tool-bar (4).*

The blades were attached to a heavy steel tool-bar (5 by 8 inches, constructed of 1-inch steel angle iron) by another plate on top of the bar and four heavy-duty (1-in. dia.) bolts.

The Gandy[1] type of insecticide dispenser was used, because it facilitates both calibration and change of rate settings in the field.

Length of the tool-bar depends on the spacing of the trees to be treated. The applicator in figure 1 was designed for trees that are small enough to be straddled by the tractor, as in nurseries and first-year plantations. The third blade shown in the photo provides stabilization to help the tractor pull straight. It is necessary because the two applicator blades are set off-center to facilitate straddling the row of trees, as illustrated in figure 2.

In young stands, the applicator blades are set about 24 inches apart, so that bands of systemic material are placed about 12 inches from each side of the tree row. When trees are too large to be straddled, the blades can be extended to the ends of the tool bar, to permit treatment of one side of a row at each end of the bar.

The device has been used very successfully to apply granular insecticides at rates as low as 5 pounds and as high as 120 pounds per acre. Raising or lowering the tool bar permits treating at any depth to 18 inches. At depths of more than 12 inches, it was found desirable to add 1,000 pounds of weight to the bar, to help hold the blades in the soil.

An important feature of the applicator is its safety. There is no operator exposure once the insecticides hopper has been filled, for metering of the dosage is controlled electrically. The chemical falls to the bottom of the slits cut by the blades and is covered as the slits close. Humans, birds, or animals are therefore very unlikely to come into contact with it.

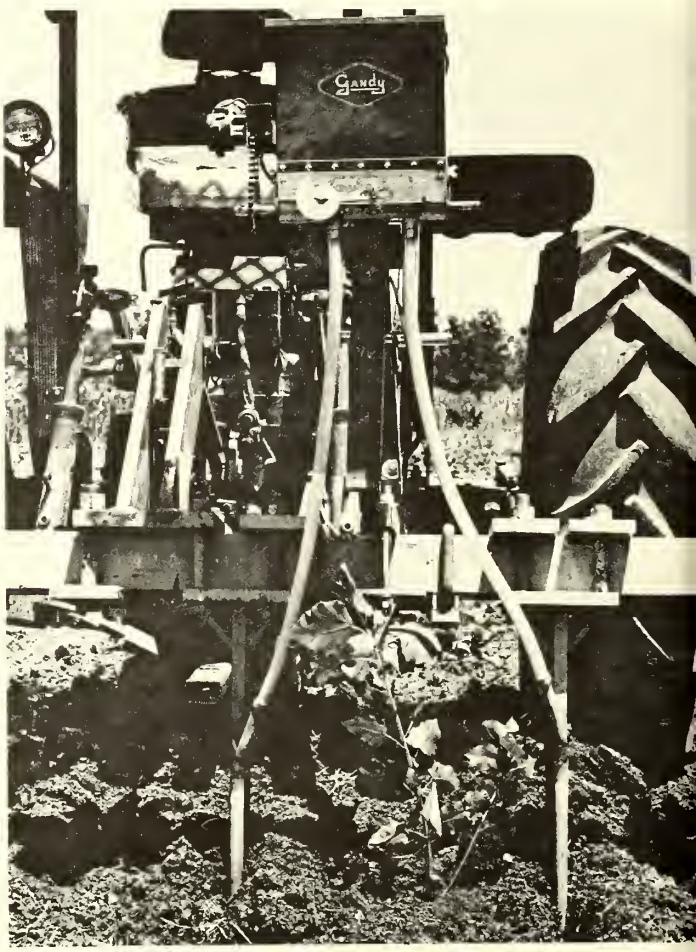

Figure 2.—***The applicator straddling a tree row and placing continuous bands of granular material 6 to 8 inches deep and about 12 inches on either side of the row.***

SOUTHERN FOREST EXPERIMENT STATION

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SO-166

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

DRIFT OF 2,4,5-T APPLIED WITH A MIST BLOWER

H. A. Brady and J. D. Walstad[1]

SOUTHERN FOREST EXPERIMENT STATION

In winds averaging 0 to 3 mph with an occasional gust to 7 mph and at temperatures of 85° to 90°F, soybean plants were damaged by drift from a skidder-mounted mist blower at distances of 510 but not 570 feet. Under these conditions, a 600 foot safety zone should be adequate for sensitive crops.

Plants were affected by spray drift at greater distances than oil-sensitive cards.

Additional keywords: Silvicide, herbicide application, herbicide drift.

Although tractor- and skidder-mounted mist blowers are effective for foliar application of herbicides to control hardwood brush (Peevy and Brady, 1968; Starr, 1964; Starr, 1972), this method of application has never been registered on the label of any herbicide used in forest management. Consultation with personnel from the Environmental Protection Agency showed that there were not enough drift measurements available upon which to base safety requirements. This note reports the distances at which soybean plants were damaged by mist blowing 2 pounds of 2,4,5-T low volatile ester in 5 gallons per acre of an oil-water formulation.

METHODS AND MATERIALS

The tank on a Potts P-48 mist blower mounted on a Clark 667 Ranger[2] skidder was filled with a 1:1:8 mixture of Esteron 245 [propylene glycol butyl ether ester of (2,4,5-trichlorophenoxy) acetic acid], diesel oil, and water. The sprayer, fitted with a ⅛ A3 Whirljet nozzle, was operated to deliver 5 gallons total volume per acre at a nozzle pressure of 15 lb/in^2 and a terminal velocity of 100 mph on the blower.

Prior to spraying, two plots were laid out in each of three types of brush stands, selected to represent a complete range of conditions likely to be encountered in forest spraying. The first area contained 34 square feet per acre of basal area in pines averaging 13.6 inches d.b.h. and 42 square feet in mixed hardwoods ranging from 3 feet tall to over 10 inches d.b.h. In the second, 20- to 22-inch pines comprised 48 to 62 square feet of basal area,

[1] The authors are, respectively, Research Soil Scientist, 1102 TMR Project, Southern Forest Experiment Station, USDA Forest Service, Pineville, La.; and Regeneration Ecologist, Southern Forestry Research Center, Weyerhaeuser Company, Hot Springs, Ark.

[2] Use of trade names is solely to identify materials used, and does not constitute endorsement by the U. S. Department of Agriculture.

and an understory of hardwood sprouts, briars, and vines averaged 3 to 10 feet tall. The third area was clearcut 2 years prior to the test, chopped with a rolling drum chopper, and burned to remove debris. No woody plants over 3 feet tall were present, but the entire area was covered with two seasons' growth of herbaceous weeds.

During the 2 days of spraying temperatures ranged from 74° to 92°; relative humidity was 65 percent in the mornings and 30 percent at midafternoon. Sustained wind velocity, measured every half hour with an anemometer on the plots, ranged from 0 to 3 mph—a few gusts to 7 mph were recorded. Wind direction was southwest to northeast throughout; thus, northeast of the sprayer was downwind and southwest was upwind.

The mist blower traveled south to north in applying sprays. Prior to spraying three paths were cleared on each side and at right angles to the sprayer line on each plot. Stakes were placed along each path at 10, 20, 30, 40, 50, 60, 80, 100, 120, 150, 180, and 210 feet from the sprayer. In one replication in the dense and one in the open stand, additional stakes were placed at 270, 330, 390, 450, 510, and 570 feet. A pot containing one to three 2-week-old soybean plants was placed by each stake. Soybeans were chosen as bioassay plants because they are very sensitive to 2,4,5-T damage and are the most common row crop on fields intermixed with southern forests. Two oil-sensitive cards were stapled to each stake, one vertically and the other horizontally.

After spraying, the oil-sensitive cards were collected and carried to the laboratory, where the percent of the surface of each card affected by spray droplets was measured.

Soybean plants were returned to the greenhouse where they were held for a week before evaluation for spray damage. They were then rated for herbicide damage on a scale of 1 to 9. On the rating scale, a value of 1 represented no detectable damage to assay plants, 3 indicated epinasty of trifoliate leaves, 6 meant leaf burning and death of the growing tip with slight browning of the plant stem, and 9 indicated that all plants in a pot were completely dead. Other numbers represented varying degrees of injury between those described.

RESULTS AND DISCUSSION

Oil-sensitive cards were not always affected by low doses of 2,4,5-T that damaged soybean plants. Droplets smaller than 50 microns, the type most likely to drift farthest from the sprayer, usually do not contain enough oil to produce a detectable spot on the cards. Brady (1972) showed earlier that the uptake of 2,4,5-T by several woody species was not closely related to the surface area wetted by the spray. Large drops were not essential for plants to receive enough herbicide to cause damage. Since the purpose of this study was to establish the distance that sensitive plants are damaged by mist-blown spray, the remainder of this discussion will concern plant response.

No differences in plant injury due to stand density occurred, probably because the plants were placed along cleared paths at right angles to the sprayer. This was recognized as a possible bias when the study was installed, but in many areas the undergrowth was so thick that it was impossible to get through except along paths.

The interaction of direction and distance proved significant for damage to soybean plants (table 1). Since the prevailing winds were from the southwest, it was no surprise that assay plants to the east of the sprayer were damaged more severely than those to the

Table 1.—*Damage to soybean plants at varying distances from mist blower. Values are averages from three forest types*

Distance from sprayer (feet)	Direction	
	Downwind	Upwind
	—— —— —— ——*Rating*—— —— —— ——	
10	8.5a[1]	7.6b
20	8.4a	7.6b
30	8.4a	7.2c
40	8.0ab	6.5de
50	7.4bc	5.1fg
60	7.0cd	5.8ef
80	6.8cd	5.2fg
100	6.5de	4.9fg
120	5.7ef	4.3gh
150	5.0fg	3.7h
180	4.5g	3.6hj
210	2.7j	2.7j

[1] Values followed by the same letter do not differ significantly at the 5-percent level by Duncan's multiple range test.

west at all distances up to 180 feet. Klingman (1964) found that a 3 mph wind displaced drops 100 microns in diameter 48 feet laterally for each 10-foot vertical drop. At 210 feet from the sprayer the difference due to direction was not statistically significant (0.05 level). Ratings beyond 210 feet were excluded from the statistical analysis because there were insufficient replications at these distances.

Some damage was found on all plants at 510 feet from the sprayer in both directions (figs. 1 and 2). Plant damage more than 400 feet upwind from the sprayer may appear excessive, but it should be remembered that the blower velocity of 100 mph can easily propell a droplet a long distance against a wind that never achieves sustained velocities above 3 mph and often is calm. At 570 feet on both sides of the sprayer all plants were undamaged.

Conclusions from this study must be limited to the conditions of the study, i.e., temperature 90°F, wind velocity 0 to 3 mph, a skidder-mounted mist blower, sprayer pressure 15 lb/in^2, and blower velocity 100 mph. Under these conditions, 600 feet should provide an adequate safety zone for sensitive plants when mist blowing 2,4,5-T.

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the

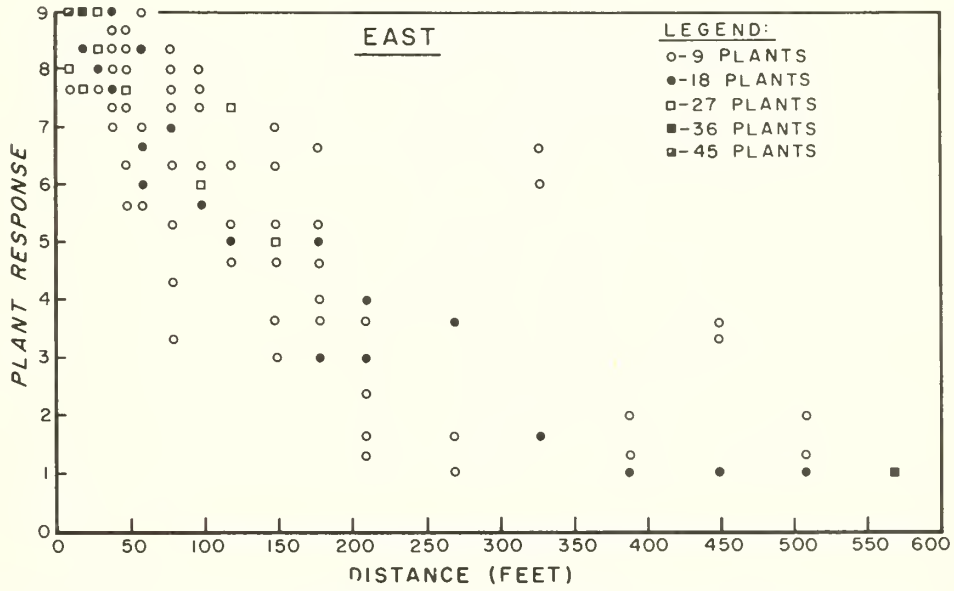

Figure 1.—*Plant damage ratings downwind from mist blower.*

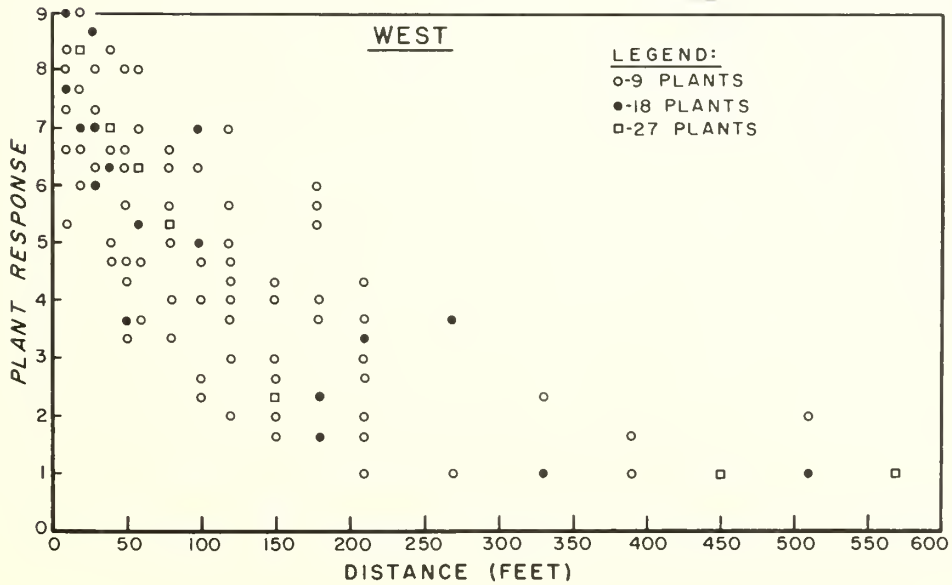

Figure 2.—*Plant damage ratings upwind from mist blower.*

uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and Federal agencies before they can be recommended.

ACKNOWLEDGMENTS

The herbicides used in this study were furnished by the Dow Chemical Company. Dr. Harvey Holt of the University of Arkansas and Mr. Hoyt Nation of Dow Chemical Company assisted with the field spray application and data collection.

LITERATURE CITED

Brady, H. A.
1972. Drop size affects absorption of 2,4,5-T by six hardwood species. Twenty-fifth South. Weed Sci. Soc. Proc., p. 282-286.

Klingman, G. C.
1964. Whirl chamber nozzles compared to other herbicide nozzles. Weeds 12: 10–14.

Peevy, F. A., and Brady, H. A.
1968. Mist blowing versus other methods of foliar spraying for hardwood control. Weed Sci. 16: 425–426.

Starr, J. W.
1964. The use of the mist blower for control of undesirable hardwoods. Miss. Agric. Exp. Stn. Bull. 692, 15 p.

Starr, J. W.
1972. The possibility of using chemicals for site preparation from ground equipment. Twenty-fifth South. Weed Sci. Soc. Proc., p. 243–247.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

SOUTHERN FOREST EXPERIMENT STATION

1973

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SO-167

Forest Service, U.S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

SEP 8 1975

WATER TABLE DEPTH AND GROWTH OF YOUNG COTTONWOOD

W. M. Broadfoot[1]

SOUTHERN FOREST EXPERIMENT STATION

Planted cottonwood grew best when the water table was about 2 feet deep, whether the tree was planted on soil with a high water table or the water table was raised 1 year after planting. Growth over a 1-foot-deep water table was about the same as over no water table, but a surface water table restricted growth of cuttings planted in the water, and killed trees planted the year before.

Additional keywords: *Populus deltoides*, soil moisture, tree growth.

The amount of soil moisture available in the growing season strongly influences survival and growth of newly planted trees. In river bottoms where cottonwood (*Populus deltoides* Bartr.) is normally planted, water table depth usually determines moisture supplies to tree roots. In some cases the table may be so near the soil surface that it limits aeration. In others, it may be at depths beyond reach of the young roots. This note reports the influence on cottonwood performance of water table raised before and 1 year after planting.

PROCEDURE

Soil from the surface foot of Robinsonville fine sandy loam was screened through 0.2-inch hardware cloth to remove debris and settled into steel barrels by gently tamping and moistening. The barrels, with volumes of about 7.5 cubic feet, had been painted on the outside with aluminum to reflect heat and minimize its absorption by the soil.

One cottonwood cutting 10 inches long was planted in each barrel of soil. All cuttings were taken from the same clone and were treated with a systemic insecticide to reduce insect attack.

At the start of the first growing season, three such barrels were assigned to each of four treatments: (1) control, no water table; (2) water table 2 feet from surface; (3) water table 1 foot from surface; and (4) water table at soil surface.

At the end of the growing season, the plants were lifted and their stems and roots were measured.

[1] The author is Principal Soil Scientist at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Miss., by the Southern Forest Experiment Station, USDA Forest Service, in cooperation with the Mississippi Agricultural & Forestry Experiment Station and the Southern Hardwood Forest Research Group.

Three barrels similarly planted were treated as controls in their first growing season and assigned to each of the four treatments at the beginning of the second growing season. Heights and diameters of the trees were measured at the beginning and end of that season. The trees were then lifted, roots and tops were separated, roots were washed and air-dried for 2 hours, and plant parts were weighed.

The assigned water levels were maintained by punching holes at appropriate points in the sides of the barrels and seeping water in at the bottom (fig. 1). Equal amounts of water were added to all barrels in periods of low rainfall. The amount used was that judged sufficient only to maintain normal welfare of the controls. Treatment means were compared by Duncan's new multiple range test with significance at the 0.05 level.

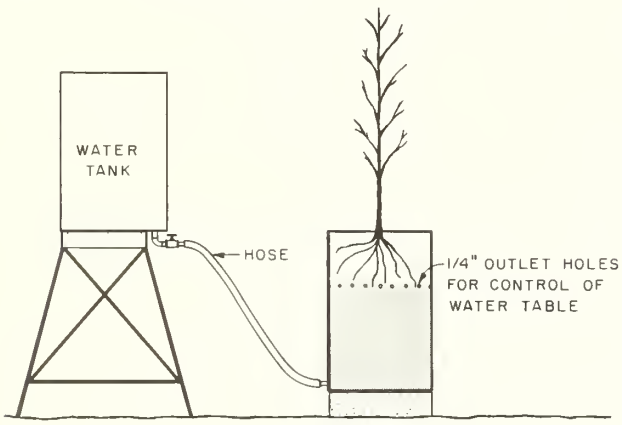
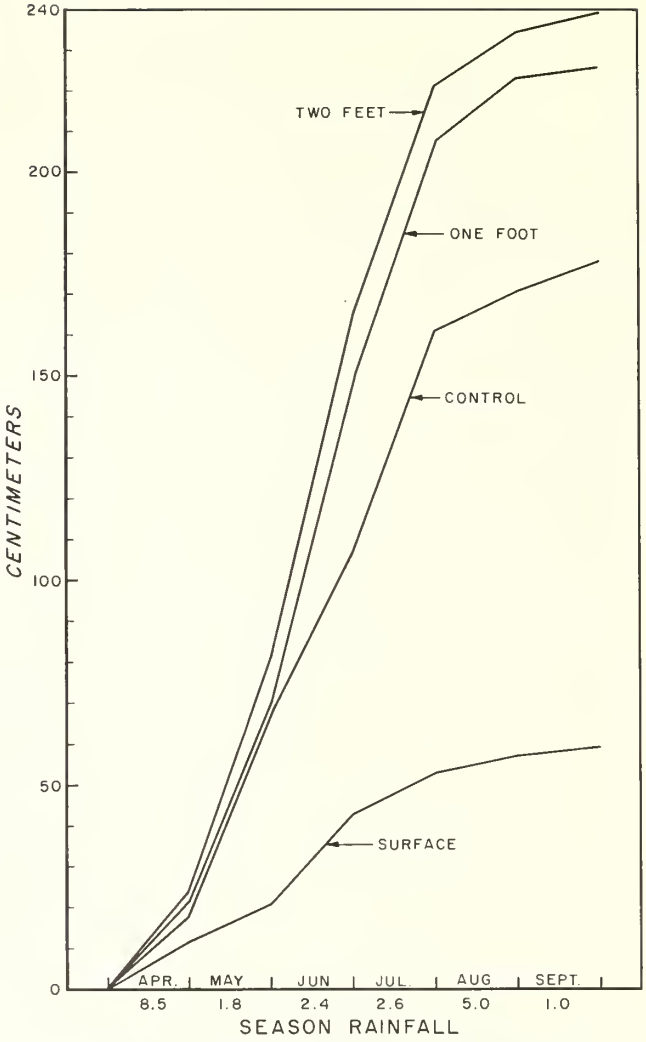


Figure 1.—*Water table in barrel set at 1 foot from soil surface.*

RESULTS

Newly Planted Cottonwood on Established Water Tables

Best height growth was made by the cottonwood cuttings where the water table was 24 inches deep (fig. 2). Growth of controls was about the same as that with 1- and 2-foot water tables during April and May, but control growth dropped in June and July, apparently due to low rainfall. Cottonwoods on 1- and 2-foot water tables continued to grow rapidly through July, but slowed sharply in August and September. Root, stem, and total plant weights were also influenced by water table depth (table 1).



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	Surface	Control	1 foot	2 feet
	——	——	*Cm* ——	——
Average height:				
Stems	58.3	177.7	225.0	239.0
	——	——	*G* ——	——
Average green weight:				
Stems	18.0	452.0	603.3	818.7
Roots	34.3	245.0	913.3	1,126.7
Total plant	52.3	697.0	1,516.6	1,945.3

Values underscored by the same line are not significantly different at the 5-percent level, according to Duncan's new multiple range test.

Root weight exceeded stem weight at all water table levels but the control, because most of the original cutting was below ground level and was included as part of the root system. In no case did the root system extend into the free water below the table level (fig. 3). Where the water table was at the surface, roots extended out from the cutting in a zone within 1 inch of the soil and water surface. The soil was gray throughout. Occasional rainshowers probably provided the surface inch or so of soil with enough oxygen to keep the plants alive through the growing season.

The results of this study indicate that cottonwood can be established and will grow satisfactorily on loamy soils with shallow water tables. But the planting will probably fail if the soil is saturated or if the free water table is at the surface during the first growing season.

Year-Old Cottonwoods

Again, the water table 24 inches from the surface was best for growth. Differences in height and root growth due to treatment were statistically significant (table 2).

Where the table level was raised to the ground surface, the plants died in late August. The control and 1-foot treatments produced similar intermediate results.

Roots grew slowly in high water tables while they developed rapidly in the control and 2-foot treatments. Even though top growth of the control and the 1-foot table was about the same, root development of the control was considerably better during the second season. The reason for the restricted root growth of the surface and 1-foot-table treatments is most likely lack of adequate aeration. The roots under water in each case were dark gray to black, and many appeared dead. Apparently, soil moisture filled the pores above the 1-foot table enough to reduce aeration and growth.

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Roots	934a	1,669ab	1,029a	1,923b
Total plant	1,687a	2,915bc	2,318ab	3,621c
	— — — — — — *Cm* — — — — — —			
Height:				
Initial	184a	168a	179a	174a
Final	209a	239ab	252b	300c
Increase	25a	71b	73b	126c
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Diameter:				
Initial	2.57a	2.47a	2.47a	2.43a
Final	3.50a	3.90b	3.70ab	3.90b
Increase	.93a	1.43b	1.23ab	1.47b

[1] Within rows, values followed by same letter do not differ significantly at the 0.05 level, according to Duncan's new multiple range test.

Figure 3.—*Cottonwood root systems after one growing season with water table at various depths.*

but not enough to kill the trees. Above the 2-foot table there was sufficient well-aerated soil along with an abundant moisture supply.

It can be safely concluded from these data that juvenile cottonwood is benefited by water tables raised into the lower portion of its normal root zone. However, where water tables are raised high enough in porous root zones to saturate the soil, death is likely to occur near the end of the second growing season.

SOUTHERN FOREST EXPERIMENT STATION

1973

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SO-168

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T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

RAISED WATER TABLES AFFECT SOUTHERN HARDWOOD GROWTH

W. M. Broadfoot[1]

SOUTHERN FOREST EXPERIMENT STATION

In natural stands near Demopolis Lock and Dam Reservoir in Alabama, the average growth in tree radius increased about 50 percent in the 5 years after the water table was raised from an indefinite depth to within reach of the tree roots. In natural stands near the Jim Woodruff Reservoir in Florida, radial growth of trees also increased markedly after the water table was raised, but only when no sediment was deposited around the trees.

Additional keywords: Tree growth, sedimentation, water impoundment.

Water that is impounded by the many dams in the South partially saturates tree-root zones nearby. The effects of these raised water tables on established forest trees and seedlings have not been reported. Yet such information is needed to fully assess the desirability of building some dams.

This paper reports the influences of raised water tables on mature hardwoods of various species that normally grow along water courses.

METHODS AND MATERIALS

Effects of raised water tables on mature trees were observed around two reservoirs of nearly constant level—the Demopolis Lock and Dam, Demopolis, Alabama, and the Jim Woodruff Reservoir near Marianna, Florida. Hardwoods adjacent to the reservoirs were selected for measurement of radial growth 5 years after water impoundment was completed.

Two increment cores were taken at right angles to each other from representative dominant or codominant trees. Average radial growth was recorded for two 5-year periods before impoundment and for the 5-year period after the water table had been raised. At each location where trees were observed, depth to capillary moisture and depth to water table were measured in auger holes. Moisture levels were measured late in the season when the soil was dry.

At the Demopolis Lock and Dam, observations were made in one general soil area and water table condition near the confluence of the Tombigbee and Black Warrior Rivers. Average values from each of several hardwood species

[1] W. M. Broadfoot, now retired, was Principal Soil Scientist at the Southern Hardwoods Laboratory. The Laboratory is maintained at Stoneville, Miss., by the Southern Forest Experiment Station, USDA Forest Service, in cooperation with the Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group.

Three barrels similarly planted were treated as controls in their first growing season and assigned to each of the four treatments at the beginning of the second growing season. Heights and diameters of the trees were measured at the beginning and end of that season. The trees were then lifted, roots and tops were separated, roots were washed and air-dried for 2 hours, and plant parts were weighed.

The assigned water levels were maintained by punching holes at appropriate points in the sides of the barrels and seeping water in at the bottom (fig. 1). Equal amounts of water were added to all barrels in periods of low rainfall. The amount used was that judged sufficient only to maintain normal welfare of the controls. Treatment means were compared by Duncan's new multiple range test with significance at the 0.05 level.

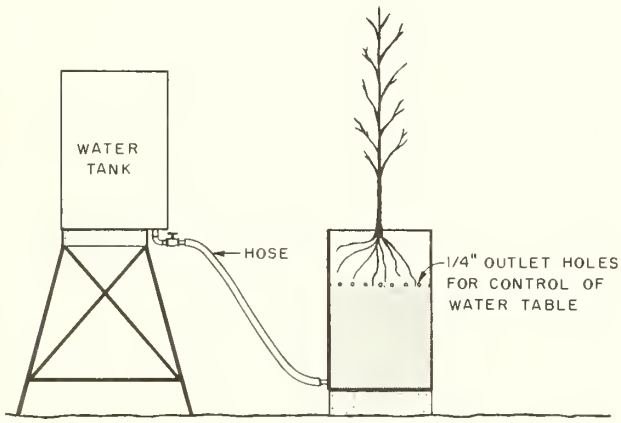
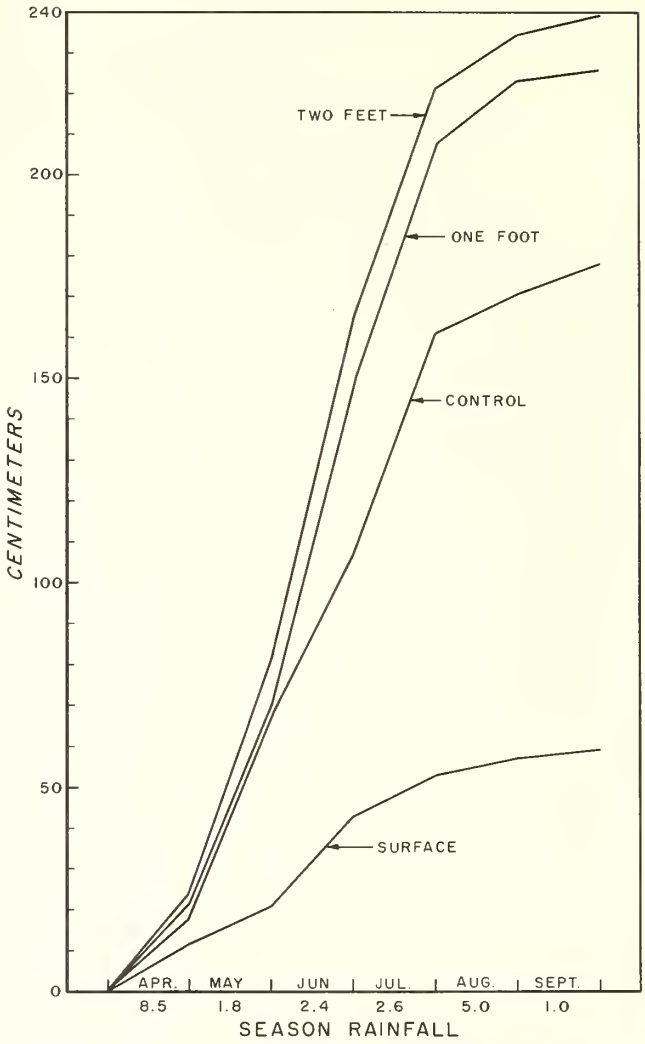


Figure 1.—*Water table in barrel set at 1 foot soil surface.*

RESULTS

Newly Planted Cottonwood on Established Water Tables

Best height growth was made by the cottonwood cuttings where the water table was 24 inches deep (fig. 2). Growth of controls was about the same as that with 1- and 2-foot water tables during April and May, but control growth dropped in June and July, apparently due to low rainfall. Cottonwoods on 1- and 2-foot water tables continued to grow rapidly through July, but slowed sharply in August and September. Root, stem, and total plant weights were also influenced by water table depth (table 1).



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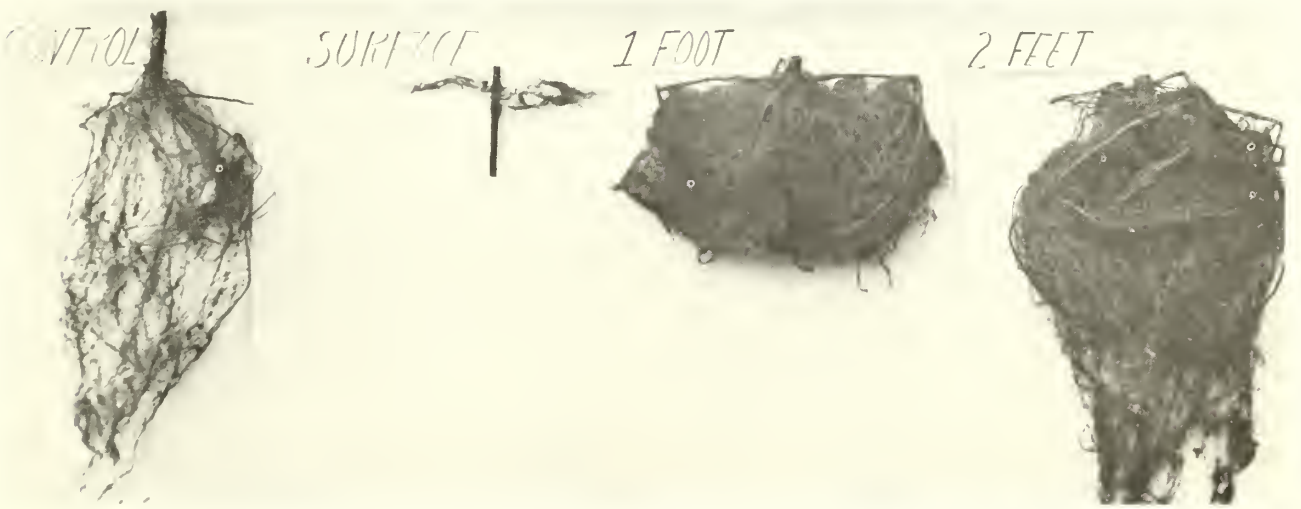

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SOUTHERN FOREST EXPERIMENT STATION

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T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

SLASH PINE SITE INDEX IN THE WEST GULF

Robert L. Bailey, William F. Mann, Jr., and Thomas E. Campbell

SOUTHERN FOREST EXPERIMENT STATION

Curves in USDA Miscellaneous Publication 50 are valid for slash pine plantations between 15 and 25 years old in the West Gulf. New curves derived from 538 data points are recommended for stands under 15 years old.

Additional keywords: *Pinus elliottii*, height growth.

Throughout the South, site index of second-growth slash pine *(Pinus elliottii* Engelm.) is often determined from curves in Miscellaneous Publication 50 (USDA Forest Service, 1929), which were developed from 111 plots distributed over the species' natural range. Since slash pine is not native to the West Gulf (west of the Mississippi River), doubts have arisen that the curves may not be applicable in that region. The study reported here indicates that those apprehensions are unjustified.

From extensive data collected in slash pine plantations on cutover sites in the West Gulf, we developed new curves. This Note describes these curves and compares them with those in Miscellaneous Publication 50 and those developed by Bennett, et al. (1959) for plantations on old fields.

METHODS

Curves were developed from a total of 538 determinations of age and average height of 15 to 50 dominants and codominants at each age (table 1). Of these, 466 were from 214 permanent plots for previous or ongoing studies, and 72 were temporary plots selected to improve the distributions of age and site index. The present data set is much stronger for low ages and high sites than Miscellaneous Publication 50 (table 2). Site index was computed with Farrar's (1973) interpolation equation for Miscellaneous Publication 50 curves.

Data were also taken at 28 points in a mixed species planting with loblolly pine. These data were not used in fitting the new guide curve but were plotted for comparisons.

Remeasurement data were judged insufficient for a polymorphic approach to site curves, and an anamorphic or guide curve technique was used. The Chapman-Richards generalization of Von Bertalanffy's equation (Pienaar

Table 1.—*Number of data points by age and site index (base 50 from Miscellaneous Publication 50 curves)*

Age (years)	Site index (feet)													
	≤45	50	55	60	65	70	75	80	85	90	95	100	105≤	TOTAL
	Number of data points													
9					1				2	3	1			7
10									1	6	8	21	8	44
11	2	1	2				1			5	2	2	4	19
12			1		1				2	3	2			9
13				2	1	3	2				2	12	30	52
14					1	2	3	12	7	12	14	13		64
15								1		2	1	3	3	10
16					5	3	7	5	3	1	9	17	18	68
17									2	17	13	4		36
18														
19							2	2	12		7	32	5	60
20								1		2	3	1		7
21					3	6	5	7	2	1				24
22							1	4		5	25	6		41
23														
24						1	4		2		4	26	14	51
25														
26														
27										3	26	10	3	42
28														
29														
30														
31										3	1			4
Total	2	1	3	2	12	15	25	32	33	63	118	147	85	538

Table 2.—*Comparison of present data base with that in Miscellaneous Publication 50*

Item	Misc. Publ. 50	Present data
	Number of data points	
Age > 40	14	0
Age ≤ 40	97	538
Age ≤ 20	46	376
Age < 10	7	51
70 ≤ S.I. ≤ 90	91 (82%)	168 (31%)
S.I. > 90	2 (2%)	350 (62%)
All data	111	538

and Turnbull, 1973) was chosen as a mathematical expression of the guide curve. It generates a sigmoid curve with intercept at the origin and inflection and upper asymptote defined by the parameters.

The equation is

$$H = a\,[1 - e^{-bA}]^c, \qquad (1)$$

where

H = average height of dominants and codominants,

A = stand age, and

a,b,c = parameters to be estimated from the data. As a function of age, site index (S), and index age (A_I),

$$H = S\left\{[1 - e^{-bA}] / [1 - e^{-bA_I}]\right\}^c. \qquad (2)$$

Equation (1) was fitted to the 538 data points with Ryshpan and Henkel's (1972) nonlinear least squares package. Parameter estimates and their 95% confidence intervals are:

$\hat{a} = 86.134 \pm 3.097$

$\hat{b} = .081 \pm .000064$

$\hat{c} = 1.866 \pm .079$.

Standard error about (1) is 5.29 feet. Goodness of fit of (2) is reflected by the narrow confidence intervals on $\hat{b}$ and $\hat{c}$.

COMPARISONS

With $\hat{b}$ and $\hat{c}$ in (2), the new curves were graphically compared with those in Miscellaneous Publication 50 and with the old-field curves of Bennett, et al. (1959). Since the maximum age in the data was 31 years, an index age of 25 was selected. The new curves nearly coincide with those in Miscellaneous Publication 50 (fig. 1). Marked departure from old-field curves is readily apparent. Further comparison was effected by drawing the new guide curve and the Miscellaneous Publication 50 curve of equal site index,

$$S = \hat{a}\,[1 - e^{-\hat{b}.25}]^{\hat{c}}$$
$$= 66 \text{ feet},$$

and plotting all data, including the 28 points in mixed stands, on a single graph (fig. 2). The guide curves extended to age 50 reach 93 feet with the Miscellaneous Publication 50 model and 83 feet with the new model. The data for the mixed stands obviously follow the Miscellaneous Publication 50 guide curve more closely.

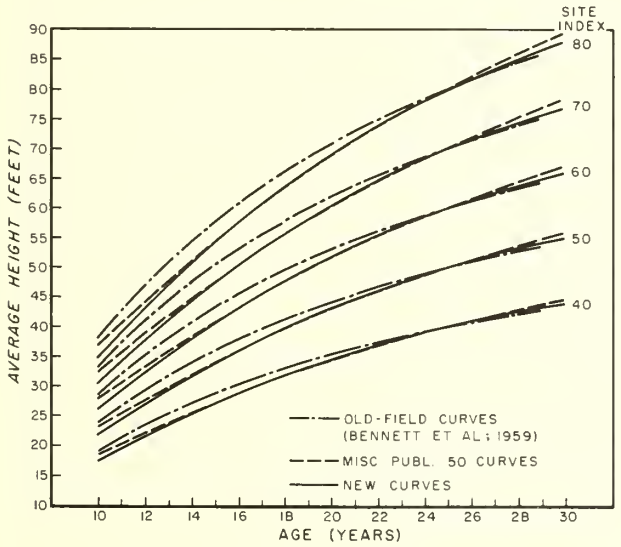

Figure 1.—*Comparison of three sets of site index curves for slash pine (index age 25).*

In two studies with a total of 80 plots, heights were measured at more than two ages. Age 25 site indices were estimated for these plots at each age with both the Miscellaneous Publication 50 and the new curves. Correlation coefficients between estimated site index and age were tested for significance at the 0.05 level. There were 16 plots with both r's significant. Of those, 8 had a larger r with Miscellaneous Publication 50 estimates. There were 17 with significant r's for the new model and 6 for Miscellaneous Publication 50 only.

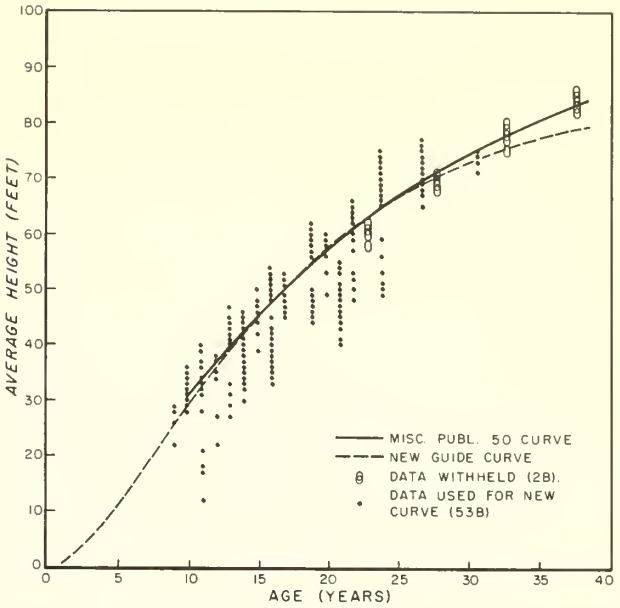

Figure 2.—*Comparison of new and Miscellaneous Publication 50 guide curves with scatter of data.*

These new curves (fig. 3), derived from plantation data on cutover sites, differ little from the regional second-growth curves in Miscellaneous Publication 50 for stands 15 years or older. However, the new model departs somewhat below age 15. It would be a better choice when using index age 25 for young stands because of its stronger data set in that range.

Some variation on individual plots may be expected regardless of model. This variation is inherent in applying any broad based model to a specific observation point. Even though 49% of the plots from two remeasurement studies showed significant trends in site index with age, the majority trend was negative for plots of one study and positive for those of the other.

LITERATURE CITED

Bennett, F. A., McGee, C. E., and Clutter, J. L. 1959. Yield of old-field slash pine plantations. USDA For. Serv. Southeast. For. Exp. Stn., Stn. Pap. 107, 19 p.

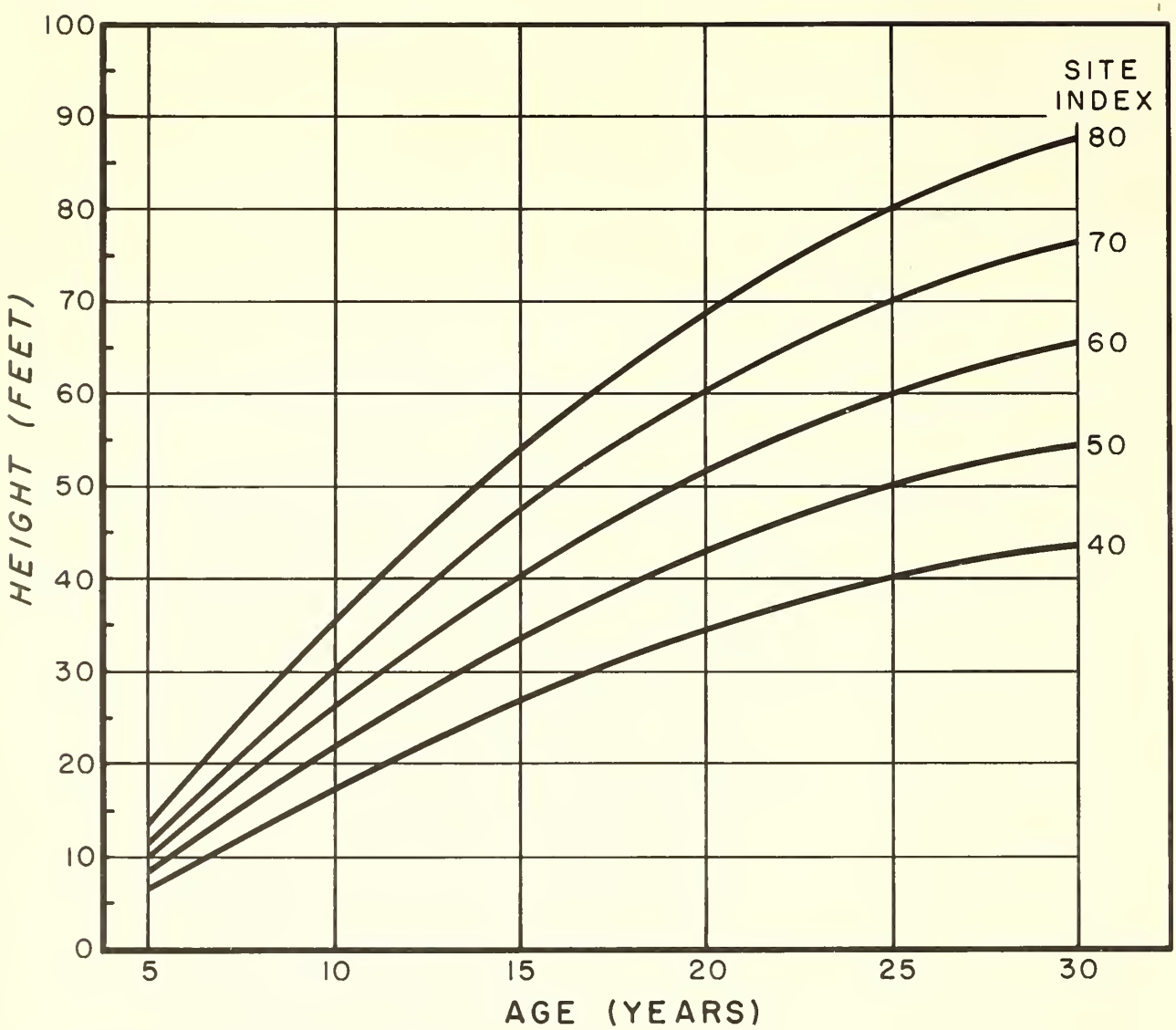

Figure 3.—*Site index curves for slash pine in the West Gulf.*

Farrar, R. M., Jr.
1973. Southern pine site index equations. J. For. 71: 696-697.

Pienaar, L. V., and Turnbull, K. J.
1973. The Chapman-Richards generalization of Von Bertalanffy's growth model for basal area growth and yield in even-aged stands. For. Sci. 19: 2-22.

Ryshpan, J., and Henkel, J.
1972. Nonlinear regression routines reference manual for the 1108. 42 p. Math. Routines Ser., Acad. Comput. Cent., Univ. Wis., Madison.

USDA Forest Service.
1929. Volume, yield, and stand tables for second-growth southern pine. USDA Misc. Publ. 50, 202 p.

SOUTHERN FOREST EXPERIMENT STATION

1973

U.S. FOREST SERVICE RESEARCH NOTE

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DEVELOPMENT OF SLASH PINE REGENERATION BENEATH OVERSTORIES

William F. Mann, Jr., and Hans G. Enghardt [1]

SOUTHERN FOREST EXPERIMENT STATION

Planted slash pines seeded abundantly on plots in central Louisiana, west of the natural range of the species. The catch from one crop was reinforced by that from another until stocking became overdense. Though results were not statistically significant, the new stands obviously developed better where the overstory was removed immediately than where 5, 10, or 20 trees per acre were retained for periods up to 12 years. Loss of growth in the new stands, however, was more than compensated by increment on the retained overstory.

Additional keywords: *Pinus elliottii,* shelterwood, seed trees.

For nearly four decades, slash pine *(Pinus elliottii* Engelm. var. *elliottii)* has been planted extensively in western Louisiana and eastern Texas, well beyond its natural range. When the stands are ready for final harvest, most landowners will probably clearcut and replant. Some, however, will prefer to attempt natural regeneration, either for reasons of utility or for aesthetic appeal near scenic and recreation areas.

This note reports a study, initiated in central Louisiana during 1952, that provided information on how young slash pines grow beneath overstories comparable in density to those left in seed-tree and shelterwood cuttings. On half of the plots, all overstory trees were removed after reproduction was well established and growth of saplings was beginning to be retarded by overhead competition. On the other half, removal will be deferred until the new stands require thinning, at about age 15 years.

STUDY METHODS

The plantation was established in 1935-1936 on an area from which the old-growth longleaf pine had been cut some years previously. Repeated wildfires had kept hardwoods to a minimum, and when the pines were planted the site was occupied chiefly by native grasses. The soil is predominantly Caddo and Beaure-

[1] **The authors: Mann is Chief Silviculturist, Timber Management Research Project 1102, Southern Forest Experiment Station, USDA Forest Service, Pineville, La. When the study was made, Enghardt was Research Forester, Louisiana Forestry Commission, assigned to Timber Management Research Project 1102. He is now with the Forstdirektion Nordbaden in Karlsruhe, West Germany.**

gard silt loam, and site index for slash pine is estimated to vary from 85 to 95 feet at age 50 years. The best sites are along intermittent drains, the poorest on flats.

Early survival was high, but the stand was gradually depleted by several wildfires and three ice storms. Trunks of about 40 percent of the trees were cankered by fusiform rust *(Cronartium fusiforme* Hedgc. & Hunt ex. Cumm.). At age 17 years, stocking was generally low, and crowns had been kept short by severe fire scorch and breakage in ice storms. Only a few trees had borne cones. In its ragged appearance, the plantation was reasonably typical of planted slash pine on thousands of acres in the general area.

Though average stocking was low, the trees were somewhat clumped. To promote crown development, the stand was cut back to 79 trees per acre in the winter of 1952-1953. Thereafter the study area was burned annually for seedbed preparation, but a good seedling catch was not obtained until the spring of 1959. In 1960, when the seedlings had become established, the overstory was cut back to 0, 5, 10, or 20 trees per acre. By this time, the live-crown ratio averaged 50 percent, and stem diameters were about 11.2 inches.

The study consists of 12 main plots, three for each overstory density. Plots were about 14 acres in size. In 1967, those with overstory trees were split, and all overstory trees were removed from half of each plot. Up to 1966, seedlings were inventoried on a single 1.6-acre area within each main plot. After the plots were split these measurement areas were retained wherever possible and new ones were established where needed. Plots from which all overstory had been removed in 1960 were not split and had only one measurement area throughout the study.

STOCKING

In the spring of 1960, shortly before the overstory was cut back to the assigned densities, yearling trees from the 1958 seed crop numbered from 1,750 to 3,350 per acre (table 1). A heavy seedfall in 1959, however, had increased initial stocking several fold, so that the total stand ranged from 7,550 to 21,350 stems per acre; one plot had 36,900. The differences were due to normal variation, for up to this time all plots had about the same number of overstory trees.

Drought and logging of the overstory caused heavy mortality in the summer of 1960. From 67 to 78 percent of the 1- and 2-year pines died, leaving stands ranging from 1,750 to 7,050 per acre.

Because continued increase in stocking was anticipated, identity of seedlings from the first 2 years was maintained. The inventory of 1961 found many germinants from the seedfall of 1960. Their density was directly related to the number of overstory trees, and ranged from 600 on clearcut plots (where seed blew in from border trees) to 6,750 on plots with 20 overstory trees per acre. Very few seedlings became established after 1961. By then the seedbed had deteriorated with reestablishment of dense grasses and an accumulation of pine straw. Moreover, any seedlings that did germinate probably were quickly overtopped by older ones. It is doubtful if a buildup in stocking is a problem after the first 3 years.

Steady mortality of seedlings from the 1960 crop continued until November 1966, when stocking had decreased by 25 to 83 percent. However, there still remained 450 to 2,800 seedlings per acre. Similarly, stocking from the 1958 and 1959 crops had declined by 79 to 90 percent. Mortality was due largely to prescribed burnings, and to a lesser degree to

Table 1.—*Seedlings per acre in two age groups, by overstory stocking levels*

Number of overstory trees per acre	May 1960		May 1961		November 1966		
	1958 crop	1959 crop	1958 and 1959 crops	Younger pines	1958 and 1959 crops	Younger seedlings	All ages
	Number						
None	2,950	18,400	7,050	600	4,200	450	4,650
5 trees	3,350	7,400	3,550	4,200	2,250	1,950	4,200
10 trees	2,250	12,850	4,250	5,500	2,250	2,800	5,050
20 trees	1,750	5,800	1,750	6,750	750	1,150	1,900

Figure 1.—Above: *Plot with 10 overstory trees per acre in March 1962. Seedlings are barely visible in heavy grass.* Below: *In 1965 a stand of nearly 4,000 seedlings per acre was growing vigorously.*

suppression and disease. Total stocking (seedlings of all ages) ranged from 1,900 to 5,050 per acre in November 1966 (table 1).

Losses were light when overstory trees were removed in the summer of 1967, and they were not clearly related to the number of trees cut (table 2). Some mortality also occurred on plots where the overstory was retained. Losses from crowding continued, and by November 1970 stocking on all plots was substantially lower than in 1966. Nevertheless, by current standards the number of stems per acre was excessive in all treatments. Subsequent stocking inventories were not made.

GROWTH OF REPRODUCTION

In the fall of 1966, immediately before the major plots were subdivided, average total height of the two largest seedlings per milacre (known to be from the 1958 and 1959 crops)

Table 2.—*Number of saplings per acre and average size at various dates*

Number of overstory trees per acre	Stocking			Avg. d.b.h. [1]	Average height [1]		Height growth
	November 1966	November 1967	November 1970	June 1972	November 1966	June 1972	1966-1972
	Number			*Inches*	*Feet*		
OVERSTORY REMOVED IN SUMMER OF 1967							
5	2,400	2,150	1,730	5.50	10.6	35.7	24.1
10	2,500	2,450	2,320	5.07	9.0	32.7	23.7
20	3,250	2,600	1,760	4.67	8.8	29.4	20.6
OVERSTORY INTACT							
5	3,650	3,600	3,100	5.03	9.8	34.7	24.9
10	4,800	4,650	3,560	4.77	8.7	33.9	25.2
20	2,170	2,070	1,920	4.17	8.0	30.5	22.5
OVERSTORY REMOVED IN 1960							
None	4,650	4,650	4,080	5.60	11.2	36.4	25.2

[1] Dominant and codominant trees from 1958 and 1959 seed crops.

averaged 11.2, 10.3, 9.0, and 7.7 feet for plots with 0, 5, 10, and 20 overstory trees. Although heights followed a logical pattern, differences were not significant when tested at the 0.1 level by analysis of variance. Lack of significance may have been due to differences in site or unequal proportions of the two ages of pines.

Average heights in 1966 changed slightly with the establishment of some new measurement plots necessitated by splitting major plots (table 2). They were consistently larger on plots scheduled for early removal of the overstory, but differences were small—0.3 to 0.8 foot. The largest trees were on plots with the overstory removed in 1960.

A special inventory was made in June 1972 to obtain average heights and diameters of dominants and codominants that originated from the 1958 and 1959 crops. Pines were bored when age was in doubt. Again differences were nonsignificant, even though heights appeared to be consistently greater under the light overstories (table 2), some of the differences amounting to 6 or 7 feet. Analysis of height growth during the years 1966-1972 also failed to show any distinct influences attributable to number of trees in the overstory or to early removal of these trees.

Average diameters of dominants and codominants in 1972 were largest on plots with the least overstory competition and on plots where the overstory had been removed in 1967. The greatest difference was 1.4 inches between plots with 20 overstory trees still standing and those on which all overstory trees had been removed in 1960. Because of the variations in density of the seedling stand, however, statistical analysis was not attempted.

GROWTH OF OVERSTORY

Overstory trees were measured in November 1960, November 1965, and January 1973. The following discussion is based on the average trees that were standing in 1973.

In 1960, at age 25, overstory trees averaged 11.2 inches in d.b.h., 57.1 feet in total height, and 19.3 cubic feet (outside bark) in merchantable volume. Wide spacing speeded diameter and volume growth. Over the 12-year period, annual growth per tree averaged 0.46 inch in diameter and 2.09 cubic feet (table 3).

Table 3.—*Growth of the average overstory tree, 1960 to 1965 and 1966 to 1973*

Periodic annual growth in	1960-1965	1966-1973	1960-1973
Volume (cu. ft., o.b.) [1]	2.15	2.02	2.09
Diameter (inch)	.49	.42	.46
Height (feet)	1.07	1.20	1.13

[1] Cubic volumes in terms of rough wood (outside bark) to a top diameter of 4 inches outside bark.

Lightning killed five trees or 3 percent of the overstory from 1960 to 1965 and three trees or 4.3 percent of the overstory from 1966 to 1973.

Average annual net growth over 12 years, with allowance for the unsalvaged volumes in the lightning-struck trees, averaged 1.92 cubic feet per tree. This value was used to estimate growth per acre for the various overstory levels. On plots where the overstory was removed in June 1967, growth over the preceding 6½ years averaged 62.4, 124.8, and 249.6 cubic feet per acre for 5, 10, and 20 overstory trees. Growth of the overstory over the 12-year period averaged 115.2, 230.4, and 460.8 cubic feet per acre for 5, 10, and 20 trees.

DISCUSSION

At one time it was feared that slash pine would not reproduce beyond its natural range in the West Gulf. This study clearly showed that, on the contrary, the major problem is overdense stands. Reproduction was abundant in 3 consecutive years, stopping only when the seedbed became unfavorable. It appears that control of stocking will require precise prescriptions for the number of seed trees and prompt removal after the new stand is established.

By statistical analysis, it could not be shown that growth of seedlings and saplings was retarded even when the 20-tree overstory was held for 12 years. On the ground, however, it is clear that development has been slowed, especially beneath and close to crowns of the large trees. If it is assumed that table 2 does describe stand conditions with reasonable accuracy, some rough calculations can be made to determine the effect of the overstory on total growth per acre.

For example, it can be hypothesized that when the stands are ready for a first thinning at age 15 years the dominants will be 7 feet taller on plots with the overstory removed in 1960 than on plots where 20 trees have been retained. A rule of thumb is that every 1-foot difference in height at age 15 years is equal to 0.5 cord per acre, and on this basis the loss in the new stand would be 3.5 cords. During the 12 years of study, however, the 20-tree overstory grew 461 cubic feet, or about 5 cords per acre; and it can be projected that 15-year growth will total 576 cubic feet or 6.4 cords per acre. If so, there will be a gain of slightly more than 3 cords per acre in total growth.

Similar comparisons with 5 or 10 overstory trees and less growth loss in the young stands also show that cordwood productivity is not decreased.

It is not the intent of this paper to attempt economic evaluations. Rather the purpose is to give increment data for the landowner to apply to his own situation. It seems evident, though, that seed-tree and light shelterwood systems can be used to regenerate slash pine without any substantial economic loss if density can be regulated reasonably well. Overstory is, of course, a problem in natural regeneration of many southern pines. If manipulation of seed trees does not provide a solution, the landowner should make a precommercial thinning at about age 3 years, reducing the stand to 750 to 1,000 stems per acre.

SOUTHERN FOREST EXPERIMENT STATION

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SEEDLING AGE INFLUENCES SURVIVAL OF CONTAINERIZED LOBLOLLY PINES

B. P. DICKERSON [1]

SOUTHERN FOREST EXPERIMENT STATION

Containerized 6-, 8-, and 10-week-old seedlings were outplanted in January, March, and April. All January seedlings died. April seedlings survived and grew better than the March, but no differences in survival due to seedling age were found. In the April planting, 10-week-old seedlings grew faster than 8-week-olds.

Additional keywords: Loblolly pine, *Pinus taeda* L., container planting, regeneration, growth, survival, erosive sites.

As loblolly pine (*Pinus taeda* L.) seedlings develop, physiological changes make them less susceptible to extreme heat, cold, and drought (Wakeley, 1954). Bare-root seedlings develop resistance to adverse conditions over a full growing season in nursery beds. Container-grown loblolly seedlings, however, may be planted when only 6 weeks old, and previous experience has shown that seedlings this young do not survive well under marginal field conditions. Reported here are survival and growth of 6-, 8-, and 10-week-old containerized loblolly pine planted on erosive sites at three different times of the year. It is believed that, up to certain limits, the older the seedling at planting time, the better the chance for survival.

METHODS

Containerized seedlings were grown for 6, 8, and 10 weeks under optimum circumstances after germination. They were then field-conditioned by subjecting them to short days and low temperatures for 2 weeks before outplanting on January 19, March 9, and April 27, 1971.

Loblolly pine seedlings from one seed lot were grown in 4½-inch plastic "bullet" containers (Walters, 1963) filled with a mixture of two parts silt soil from an existing loblolly pine plantation, one part peat, and one part coarse sand. Dry, pulverized fertilizers were incorporated into the soil mix at the rate of 29.0 grams of ammonium nitrate, 24.0 grams standard superphosphate (20 percent available), and 10.8 grams of muriate of potash per 1,000 bullets. In pot and field trials, this level of fertilization proved optimum for growth.[2]

[1] The author is associate silviculturist at the Forest Hydrology Laboratory which is maintained at Oxford, Miss., by Southern Forest Experiment Station, U.S. Forest Service, in cooperation with the University of Mississippi. The study described was done in cooperation with the Yazoo-Little Tallahatchie Flood Prevention Project.

[2] Personal communication with Paul Duffy, Forest Hydrology Laboratory.

Sowing dates were staggered so that all three age classes were ready for outplanting on each assigned date. Containers were prepared 13, 11, and 9 weeks prior to the three planting dates to allow additional time for germination and field conditioning.

Filled containers were placed in a greenhouse which was kept between 64 and 80 degrees F. Germination was completed within 10 days. Artificial light was used to supplement normal daylight and provide a 14-hour light period. Seedlings were watered as necessary to ensure adequate moisture for germination and growth.

Two weeks before outplanting, all seedlings were placed in a growth chamber where temperature and light duration were periodically reduced to condition the plants. The reduction sequence was:

Days in chamber	Light duration	Temperature	
		Night	Day
(Number)	*(Hours)*	*(Degrees F)*	
2	12	50	70
2	10	46	64
3	9	41	55
7	8	39	50

Upon removal from the growth chamber, seedlings were root-pruned flush with the bullet container, and only healthy, vigorous seedlings outplanted.

Just before outplanting, five groups of 10 seedlings each were randomly selected from each treatment for measurement of seedling characteristics. Stem heights were measured to the nearest centimeter and stem diameters at groundline to the nearest millimeter. The number of secondary needle fascicles and needle buds on each seedling were also recorded. Percent germination was not as high as was anticipated, limiting the number of seedlings available for determining shoot/root ratios. Roots of seedlings from two to three of the previously selected groups were pruned flush with the plastic container and seedlings separated from container and soil. Shoot/root ratios were computed from ovendry weights.

Bullets were planted on the grounds of the Forest Hydrology Laboratory at Oxford, Mississippi. The soil had been compacted by mechanical grading, and establishing pine had proved difficult in previous studies.

Planting was in a randomized block design. Three separate blocks, approximately 1/10 acre in size, with nine plots per block, were delineated. All blocks were within a 3-acre area. Individual plots measured 14 by 24 feet and accommodated 50 seedlings on a 2- by 2 foot spacing plus an isolation strip. All plots were cleared of other vegetation and kept clean during the first growing season.

Immediately after planting, seedling heights were measured to the nearest 1/10 foot. Height and survival were measured in November 1971 and 1972.

Differences in growth and survival results at the end of the study were examined by analysis of variance. All results were tested for statistical significance at the 1-percent level.

RESULTS AND DISCUSSION

Survival

All the seedlings planted in January died, apparently because they were conditioned for extremely cold weather. Minimum temperatures on the 2 days immediately after planting reached 8°F. Temperatures then were mild for several weeks, often reaching the mid-sixties. In early February minimum temperatures dropped sharply, this time to —2°F. The seedlings were not cold-hardy after the extended period of mild temperatures, and the sudden freeze probably was the cause of death (Levitt, 1966).

In the analysis of unadjusted data, survival in the April planting was significantly better than in the March planting (table 1). No significant differences resulted from age of seedlings or interactions.

Mortality resulting from rabbit damage was high for the March planting. When adjusted to exclude mortality from rabbit damage, the average survival of the March planting increased 10 percent and the survival for the April planting only 1 percent (table 1). Differences in survival of the adjusted data were no longer significant.

No significant differences due to age of seedlings at planting time were found, but in both the adjusted and unadjusted April results (table 1) survival appeared to increase with age. This trend was not apparent in the March planting.

Table 1.—*Average survival and growth at the end of the first and second growing seasons*

Planting date	Seedling age	November 1971		November 1972		
		Survival	Total height	Survival	Adjusted survival [1]	Total height
	Weeks	*Percent*	*Feet*	*Percent*	*Percent*	*Feet*
March	6	66	0.5	66	74	1.6
	8	54	.3	53	69	1.3
	10	68	.4	65	69	1.5
	Average all ages	63	.4	61	71	1.5
April	6	78	.4	76	76	1.6
	8	83	.4	82	83	1.7
	10	91	.6	91	92	2.1
	Average all ages	84	.5	83	84	1.8

[1] Excludes mortality from rabbit damage.

Growth

When planted, all container stock averaged 0.2 foot tall. In one growing season, total height increased 100 percent, to an average of 0.4 foot. After two growing seasons, seedling height averaged 1.6 feet, an 800-percent increase over initial height (table 1). This percent increase is equal to that observed for bare-root stock previously planted on the same area.

In the second growing season the April planting grew significantly better than the March. There was no difference in growth between the 6-week seedlings and the average of th 8- and 10-week seedlings. Growth of the 10-week seedlings was significantly better than growth of the 8-week seedlings.

Seedling Charcteristics

For each planting date, total heights, shoot/root ratios, and total weights of seeedlings of various ages were tested for differences between the 6- and the average of 8- and 10-week seedlings and between the 8- and 10-week seedlings. In the January and April plantings, the 6-week seedlings were shorter and weighed less than the other age seedlings (table 2). In the March planting, no differences were significant.

In January and April, the percentage of seedlings having secondary needles or buds varied distinctly by age class (table 2). None of the 6-week seedlings, slightly over half of the 8-week seedlings, and almost all of the 10-week seedlings had secondary needles. In

Table 2.—*Characteristics of seedlings at planting time*

Planting date	Seedling age	Total height	Diameter	Seedling means [1]; ovendry weight			Shoot/root ratio by weight	Seedlings with secondary needles
				Shoot	Root	Total		
	Weeks	*Cm*	*Mm*	*Grams*				*Percent*
January	6	4.6	1.1	0.05	0.01	0.06	3.6	0
	8	6.4	1.3	.11	.03	.14	4.2	68
	10	7.2	1.3	.15	.03	.18	4.5	90
March	6	4.7	1.1	.06	.03	.09	2.8	26
	8	5.1	1.1	.08	.03	.11	3.1	46
	10	5.0	1.2	.08	.02	.10	3.1	60
April	6	3.6	1.0	.03	.01	.04	3.5	0
	8	5.7	1.1	.08	.02	.10	3.4	62
	10	7.0	1.2	.13	.03	.16	4.5	100

[1] Means connected by lines are significantly different (1 percent level).

the March seedlings, differences between age classes were less pronounced and seedlings having secondary needles or buds ranged from 26 percent for the 6-week to 60 percent for the 10-week (table 2).

Calendar age is not the proper criterion for determining survival and growth potential of containerized seedlings. A better means would be morphological grading. For example, seedling height, weight, shoot/root ratio, and presence of secondary needles or buds may be directly related to survival and growth. No differences due to age were found in either seedling characteristics or resultant growth and survival of March seedlings. However, there were differences among the characteristics of the three age classes of the April seedlings and the advantage of older and larger seedlings, although not confirmed statistically, was reflected in their field performance.

LITERATURE CITED

Levitt, S.
1966. Winter hardiness in plants. *In* Mergman, H. T. (Ed.) Cryobiology, p. 495-563. Academic Press, New York.

Wakeley, P. C.
1954. Planting the southern pines. USDA Agric. Monogr. 18, 233 p.

Walters, J.
1963. An improved planting gun and bullet: a new tree-planting technique. USDA Forest Serv. Tree Planters' Notes 57: 1-3.

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STEREORADIOGRAPHIC TECHNIQUE FOR OBSERVING SEEDS AT SHORT VIEWING DISTANCE

J. A. Vozzo [1]

SOUTHERN FOREST EXPERIMENT STATION

Stereoradiographs provide finer detail when the viewing distance is short. The preparation of stereoradiographs to be viewed at 5 cm and the construction of a viewing apparatus are described.

Additional keywords. X-ray, seed testing.

Stereoradiographs of seeds or other small objects reveal detailed structures and clarify relationships among superimposed forms. However, medical techniques for preparing stereoradiographs require relatively long viewing distances (60-75 cm), which may cause loss of resolution and compromising of fine detail (Eastman Kodak 1968, 1970). The procedure described here provides a full stereoscopic effect for radiographs exposed at normal tube-to-object distances and viewed at 5 cm.

This technique is well suited to small, inanimate objects that can be fixed to a cardboard base. The base acts as both support and reference point. With small objects, two images can appear on one sheet of radiographic film, thus assuring the same development for both.

[1] The author is Plant Physiologist at the Forest Tree Seed Laboratory, maintained at Mississippi State, Mississippi, by the Southern Forest Experiment Station in cooperation with Mississippi State University.

Because the radiography unit used in this study has an immobile tube, an object shift was necessary. For a unit with a movable tube, the procedure would be similar except that the tube is shifted and the object fixed.

PROCEDURE

Glue the object to a heavy cardboard base with lines drawn at the midpoints of all four sides. Carefully draw a reference line (AB) down the center of the film envelope. Draw two lines (CD and EF) parallel to AB and exactly 25 mm on either side of it. Next, draw a line (GH) through the center of the envelope and perpendicular to CD and EF (fig. 1). These lines will serve as references for shifting the object.

Center the film envelope under the tube. Place the object on the film and align the four marks on the cardboard base with lines CD and GH (fig. 1). The center of the film envelope should be directly under the tube (fig. 2). Shield the left half of the film with lead and expose as for a usual radiograph.

Shift the object 50 mm to the other guidelines, making certain the base is accurately

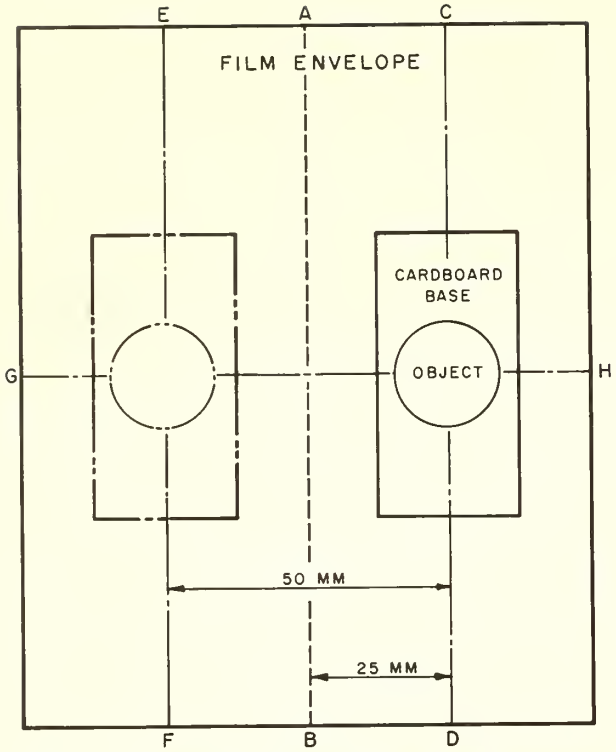

Figure 1.—*Positions of object, base, and reference lines on film envelope.*

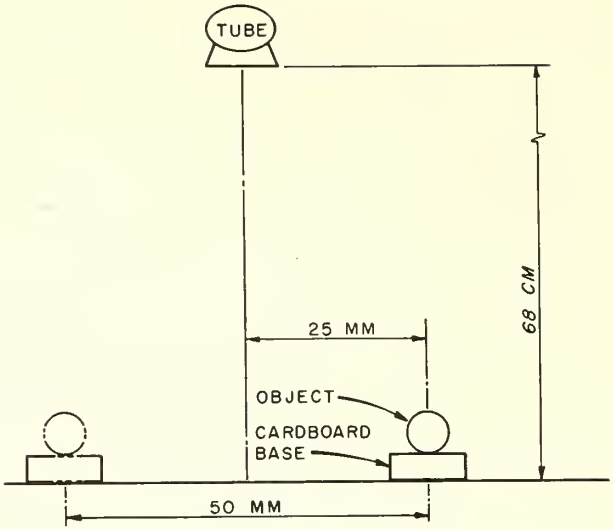

Figure 2.—*Relation of object, tube, and object shift.*

aligned. Shield the film with lead and make the same exposure as for the first image. Develop the radiograph in the usual manner.

Stereoradiographs require special viewers, which are available commercially. An inexpensive viewer that allows a 5 cm viewing distance can be adapted from common laboratory instruments. The viewer consists of four pieces: (1) an illuminator, (2) a stand from a disecting microscope, (3) a stereoscope, and (4) rails for aligning the stereoscope. Place the illuminator on the microscope stage and prop the far ends to make it level. Attach guides to the stereoscope so that it can longitudinally traverse the rails. Make the rails from Plexiglas. Place the rails on top of the microscope arm, and rest the stereoscope on the rails (fig. 3).

Position the stereoradiograph on the illuminator and under the stereoscope. Adjust the stereoscope for interpupillary distance, then

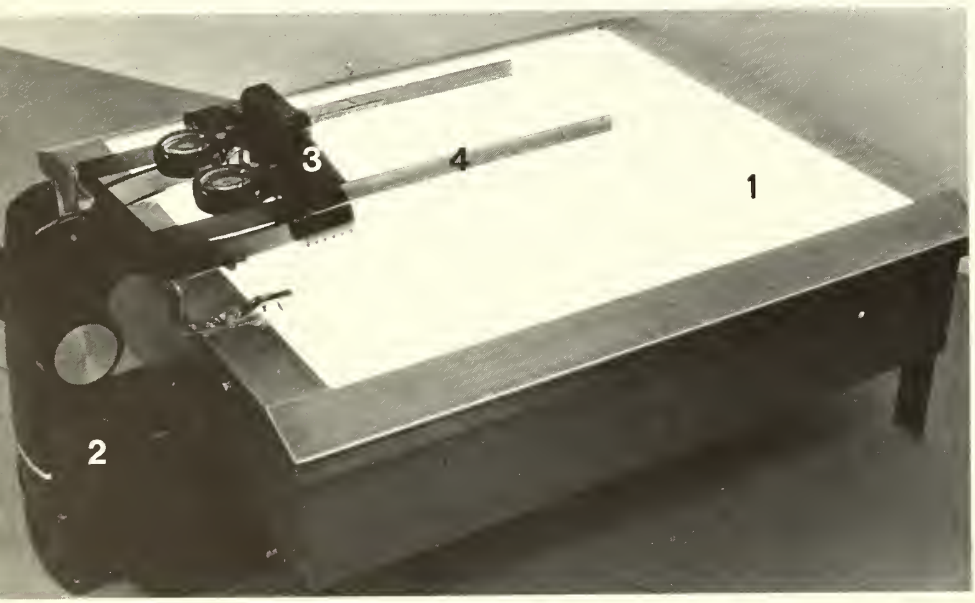

Figure 3.—*The stereoradiographic viewing instrument is composed of (1) an illuminator, (2) a microscope stand, (3) a stereoscope, and (4) aligning rails.*

focus the image by moving the microscope arm up or down. This focus requires only a slight depth adjustment. If the stereoradiograph contains more than one object, view each individually, advancing the stereoscope along the rails. The stereoscopic effect may be distorted unless the viewer is directly over the image.

The 50 mm object shift will regularly produce the stereoscopic effect using this equipment (an Abrams 2-4 stereoscope Model CB -1).[2] If a different stereoscope is used, the distance of the object shift may need adjustment. The rest of the procedure should remain the same.

[2] Mention of trade names is solely to identify equipment used and does not imply endorsement by the U. S. Department of Agriculture.

LITERATURE CITED

Eastman Kodak.
1968. The fundamentals of radiography. 11th ed., 76 p. Radiography Markets Div., Rochester, N. Y.

Eastman Kodak.
1970. Radiography in modern industry. 3rd ed., 160 p. Radiography Markets Div., Rochester, N. Y.

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FIRST-YEAR REVEGETATION FOLLOWING TIMBER HARVEST IN EAST TEXAS

J. J. Stransky, E. S. Nixon, C. L. Burandt, Jr., and R. L. Willett[1]

SOUTHERN FOREST EXPERIMENT STATION

During the first growing season after clearcutting and burning, herbaceous plants quickly occupied an open area in a loblolly-shortleaf pine-hardwood forest of east Texas. The clearcut area was dominated by the herbaceous species Nothoscordum bivalve, Oxalis dillenii, *and* Gnaphalium purpureum; *abundant woody species were* Rhus toxicodendron, Rubus *spp., and* Rhus copallina. *In an adjacent wooded area, dominant understory species were* Nothoscordum bivalve *and* Chasmantheum sessiliflorum.

Additional keywords: Clearcutting, *Pinus taeda, P. echinata*, understory growth.

Clearcutting, burning, and planting are efficient means of harvesting and regenerating southern pines; but the environmental effects have not been adequately documented. Will life-supporting vegetation quickly occupy a clearcut area? How will these plants differ from those growing beneath trees? Such questions must be answered if forests are to provide both timber and wildlife habitats, if they are to be both productive and aesthetically pleasing. In the present study, plant species occurring in clearcut and forested areas of east Texas are compared for one growing season after cutting.

STUDY AREA DESCRIPTION

The study site is about 15 miles south of Nacogdoches, Texas, in an upland forest dominated by *Pinus taeda, P. echinata, Liquidambar styraciflua,* and *Quercus falcata.* Vegetation analyses of nearby forested areas were recently reported by Schuster (1967) and Sullivan and Nixon (1971).

Topography ranges from nearly level to rolling. Elevation is about 283 feet above sea level. The area is part of the Gulf Coastal Plain's tertiary and quaternary deposits. The soils belong to the Ruston, Kalmia, Caddo, and Boswell series, developed over acid clayey sediments.

Ruston sandy loam soil is found on a nearly level ridge. It is a well drained soil that occupies about 78% of the study area.

Kalmia fine sandy loam soil situated on a gentle south slope makes up about 12% of the area.

1 Stransky is stationed at the Wildlife Habitat and Silviculture Laboratory, which is maintained at Nacogdoches, Texas, by the Southern Forest Experiment Station, USDA Forest Service, in cooperation with the School of Forestry, Stephen F. Austin State University. Nixon is a professor, and Burandt and Willett are graduate students at Stephen F. Austin State University.

It is less well drained than the adjacent Ruston.

Caddo very fine sandy loam soil occupies about 5% of the study area and is found in an upland depression and an adjoining minor drainageway. The water table is at or near the surface during rain periods, thus root penetration is shallow.

Boswell very fine sandy loam soil occupies about 5% of the study area. It is a deep, moderately well drained soil with a fine textured surface underlain by firm red clay. This soil occurs below the Kalmia soil on the lower slope.

All these soils, except the Boswell and portions of the Caddo, were once cleared for agriculture but reverted to timber 30 to 40 years ago.

Average annual precipitation is about 48 inches. Rainfall is heaviest in April, May, and the winter months; lowest rainfall is in August and October. Winters are mild; and summers, warm and humid.

METHODS

In May 1970, all merchantable pines were cleared from a strip 1,453.4 feet long and 449.5 feet wide. The long axis of the strip is north-south oriented.

Logging slash, unmerchantable pines and hardwoods, and the understory shrubs, vines, and herbaceous vegetation were cut with a Marden brush chopper and burned in late December 1970. A few scattered individuals of *Liquidambar styraciflua*, *Nyssa sylvatica*, *Quercus alba*, *Q. falcata*, *Q. nigra*, and *Q. stellata* were left standing. The area was planted to *Pinus taeda* seedlings in January and February 1971. The understory of the adjacent uncut forest was burned in February of the same year.

In early March, vegetation sampling plots were located along 21 randomly selected transects paralleling the short axis of the strip. Six sampling points were staked along each transect, three in the uncut woods and three in the open area. Points were spaced 32, 98, and 164 feet from the forest edge.

Herbaceous species were counted on 10.7 ft^2 plots during March, April, May, June, August, September, and October. Woody plants were tallied on 43.0 ft^2 plots in August 1971.

Density and frequency data for herbaceous species were based on counts at the peak of their flowering periods. The importance values, the sum of relative density and relative frequency (Daubenmire, 1968), were calculated for all recorded species.

Taxonomic nomenclature followed Correll and Johnston (1970). Plants not readily recognized were later identified at the USDA Forest Service Herbarium, Fort Collins, Colorado.

RESULTS AND DISCUSSION

Herbaceous Species

Within one growing season, herbaceous vegetation occupied the area. A total of 105 species representing 28 families were recorded (table 1). Twenty-five species in Gramineae, 24 in Compositae, and 13 in Leguminosae accounted for 59% of the total. Other families had five species or less. Thirty-eight percent were annuals, 53% perennials, and the remaining 9% biennial or variable in longevity.

Ten non-native species grew in the area: *Briza minor*, *Lolium perenne*, *Trifolium reflexum*, and *Verbascum thapsus* from Europe, *Bromus japonicus* and *Digitaria violascens* from Asia, *Facelis retusa* and *Paspalum urvillei* from South America, *Linum medium* from the midwestern United States, and *Gnaphalium falcatum* probably of South American origin. *Digitaria* and *Linum* were most abundant. All grew only in the open, except *Verbascum* which occurred both in the open and the woods.

The herbaceous species were most abundant in the open. Sixty-eight percent grew only in the open, 7% only in the woods, and 25% in both the wooded and open areas. In the open, species with the highest importance values were *Oxalis dillenii*, *Gnaphalium purpureum*, *Nothoscordum bivalve*, and *Chasmanthium sessiliflorum*. The latter two were also dominant in the woods. Species in the Gramineae, Cyperaceae, and Juncaceae families comprised 30.6% of the total herbaceous species in the open (30 out of 98) but only 21.2% of those in the woods (7 out of 33). These findings agree with those of Schuster (1967).

Species distribution was also influenced by the different soils in the area. About one-third of the herbaceous species occurred on all four soil types. But *Carex complanata* and *Juncus biflorus* were found only on the seasonally wet Caddo soil; and *Briza minor*, *Cyperus refractus*, and *Erechtites hieracifolia*, only on the Boswell soil. Thirty-six species grew only on the Ruston soil that had once been cultivated; those with the

Table 1.—*Importance value, seasonal dominance, and longevity of herbaceous species recorded on the experimental area*

Plant family and species	Importance value		Month of dominance	Longevity
	Open	Woods		
Gramineae				
Agrostis elliottiana Schult.	0.5	...	April	Ann.
Aira elegans Gaud.	1.9	...	May	Ann.
Andropogon virginicus L.	2.2	...	October	Per.
Aristida longespica Poir.	.7	...	September	Ann.
Aristida virgata Trin.	1.1	3.6	September	Per.
Briza minor L.	.1	...	May	Ann.
Bromus japonicus L.	.1	...	May	Ann.
Chasmanthium sessiliflorum (Poir.) Yates	11.3	48.1	June	Per.
Digitaria violascens Link.	1.8	...	May	Ann.
Eragrostis hirsuta (Michx.) Nees.	2.3	.8	September	Per.
Lolium perenne L.	.1	...	May	Per.
Panicum aciculare Poir.	1.0	...	May	Per.
Panicum anceps Michx.	.2	.6	September	Per.
Panicum boscii Poir. var. *molle* (Vasey) Hitchc. & Chase	1.9	...	May	Per.
Panicum brachyanthum Steud.	5.4	...	September	Ann.
Panicum laxiflorum Lam.	.7	...	May	Per.
Panicum lindheimeri Nash.	3.9	...	May	Per.
Panicum linearifolium Scribn.	.6	...	May	Per.
Panicum scribnerianum Nash.	1.4	...	May	Per.
Panicum sphaerocarpon Ell.	1.0	...	June	Per.
Paspalum laeve Michx.	.1	...	August	Per.
Paspalum setaceum Michx.	.1	.6	May	Per.
Paspalum urvillei Steud.	.7	...	June	Per.
Schizachyrium scoparium (Michx.) Nash.	...	2.4	September	Per.
Tridens flavus (L.) Hitchc.	.2	...	October	Per.
Compositae				
Ambrosia artemisiifolia L.	5.4	3.0	September	Ann.
Cirsium spp.	.7	...	May	Per.
Conyza canadensis (L.) Cronq.	7.1	1.6	August	Ann.
Elephantopus carolinianus Raeusch.	.9	.6	August	Per.
Erechtites hieracifolia (L.) Raf. var. *intermedia* Fern.	...	.6	September	Ann.
Erigeron strigosus Willd.	1.7	...	May	Per.
Eupatorium capillifolium (Lam.) Small	.3	...	October	Per.
Eupatorium compositifolium Walt.	.8	...	October	Per.
Eupatorium serotinum Michx.	.9	...	September	Per.
Facelis retusa (Lam.) Sch. Bip.	.8	...	May	Ann.
Gnaphalium falcatum Lam.	.6	...	April	Ann.
Gnaphalium pensilvanicum Willd.	1.9	...	May	A. or Bienn.
Gnaphalium purpureum L.	13.0	...	May	Ann.
Helenium amarun (Raf.) Rock.	.1	...	May	Ann.
Helianthus hirsutus Raf.	.3	2.2	June	Per.
Heterotheca pilosa (Nutt.) Shinners	2.2	...	June	Ann.
Krigia oppositifolia Raf.	.5	...	April	Ann.
Lactuca floridana (L.) Gaertn.	.5	...	June	Ann.
Pluchea camphorata (L.) DC.	.1	...	September	A. or Per.
Pyrrhopappus carolinianus (Walt.) DC.	1.4	...	May	Ann.
Rudbeckia hirta L.	5.1	...	May	Ann.
Senecio ampullaceus Hook	.1	...	April	Ann.

Table 1.—*Importance value, seasonal dominance, and longevity of herbaceous species recorded on the experimental area* (Continued)

Plant family and species	Importance value		Month of dominance	Longevity
	Open	Woods		
Solidago rugosa Ait. var. *celtidifolia* (Small) Fern.	...	0.7	September	Per.
Vernonia texana (Gray) Small	.6	...	August	Per.
Leguminosae				
Cassia fasciculata Michx. var. *faseiculata*	3.6	.6	June	Ann.
Desmodium laevigatum (Nutt.) DC.	.1	...	September	Per.
Desmodium paniculatum (L.) DC. var. *paniculatum*	1.5	2.1	September	Per.
Desmodium scssilifolium (Torr.) T&G	.6	3.0	September	Per.
Desmodium viridiflorum (L.) DC.	.2	...	September	Per.
Galactia volubilis (L.) Britt.	1.5	3.2	August	Per.
Lespedeza procumbens Michx.	...	.8	August	Per.
Lespedeza repens (L.) Bart.	.2	...	August	Per.
Lespedeza stuevei Nutt.	.6	1.4	September	Per.
Schrankia uncinata Willd.	...	.7	June	Per.
Strophostyles umbellata (Willd.) Britt.	.4	...	September	Per.
Stylosanthes biflora (L.) B.S.P.	.8	1.8	May	Per.
Trifolium reflexum L.	.1	...	April	Ann.
Cyperaceae				
Carex complanata T&H	.1	...	May	Per.
Cyperus refractus Steud. emend. Boeck	.1	...	May	Per.
Cyperus retrorsus Chapm.	1.0	...	June	Per.
Scirpus koilolepis (Steud.) Gl.	4.6	...	March	Ann.
Scleria oligantha Michx.	2.3	9.8	May	Per.
Euphorbiaceae				
Acalypha gracilens Gray	2.6	.6	June	Ann.
Acalypha virginica L.	3.8	...	June	Ann.
Croton capitatus Michx.	5.3	...	August	Ann.
Euphorbia maculata L.	.3	...	August	Ann.
Tragia urticifolia Michx.	.1	.7	May	Per.
Rubiaceae				
Diodia teres Walt.	...	2.5	May	Ann.
Hedyotis australis Lewis & Moore	2.2	...	March	Ann.
Hedyotis crassifolia Raf.	8.2	...	April	Ann.
Solanaceae				
Physalis heterophylla Nees. var. *heterophylla* sens. lat.	1.6	2.8	May	Per.
Solanum americanum Mill.	.4	.7	May	Ann.
Solanum carolinense L.	.7	...	May	Per.
Campanulaceae				
Triodanis biflora (R&P.) Greene	.6	...	May	Ann.
Triodanis perfoliata (L.) Nieuw.	.9	...	May	Ann.
Labiatae				
Monarda punctata L.	.2	...	June	A. or Per.
Salvia lyrata L.	.1	...	April	Per.

Table 1.—*Importance value, seasonal dominance, and longevity of herbaceous species recorded on the experimental area* (Continued)

Plant family and species	Importance value		Month of dominance	Longevity
	Open	Woods		
Liliaceae				
Allium canadense L. var. *canadense*	0.7	...	April	P. or Bienn.
Nothoscordum bivalve (L.) Britt.	26.5	91.9	March	Per.
Onagraceae				
Oenothera laciniata Hill.	2.4	...	May	Ann.
Oenothera spachiana T&G	...	.6	May	Ann.
Scrophulariaceae				
Linaria canadensis (L.) Dum.	.6	...	May	Ann.
Verbascum thapsus L.	.2	.6	May	Bienn.
Umbelliferae				
Daucus pusillus Michx.	.2	...	May	Ann.
Sanicula canadensis L.	2.8	.6	May	Bienn.
Amaryllidaceae				
Hypoxis hirsuta (L.) Cov.	.9	2.8	May	Per.
Cistaceae				
Lechea mucronata Raf.	4.1	...	August	Per.
Geraniaceae				
Geranium carolinianum L.	1.2	...	April	A. or Bienn.
Iridaceae				
Sisyrinchium sagittiferum Bickn.	.4	...	April	Per.
Juncaceae				
Juncus biflorus Ell.	.1	...	May	Per.
Linaceae				
Linum medium (Planch.) Britt. var. *texanum* (Planch.) Fern.	2.6	...	May	Per.
Loganiaceae				
Polypremum procumbens L.	.8	...	May	A. or Per.
Oxalidaceae				
Oxalis dillenii Jacq.	15.5	2.9	May	Ann.
Plantaginaceae				
Plantago virginica L.	7.5	...	April	Ann.
Polygonaceae				
Rumex hastatulus Ell.	.2	...	May	Per.
Polypodiaceae				
Pteridium aquilinum (L.) Kuhn var. *pseudocaudatum* (Clute) Heller	.1	...	April	Per.
Saxifragaceae				
Lepuropetalon spathulatum (Muhl.) Ell.	1.4	...	March	Ann.
Valerianaceae				
Valerianella stenocarpa (Engelm.) Krok var. *stenocarpa*	.7	...	April	A. or Bienn.
Verbenaceae				
Verbena halei Small	.1	...	April	Per.
Violaceae				
Viola septemloba Le Conte	1.0	2.9	April	Per.

highest importance values were *Hedyotis crassifolia* and *Scirpus koilolepis*.

Throughout the growing season new species appeared in the area, and dominance shifted from one species to another.

In the March sampling only four species were tallied, three annuals and one perennial (table 1). *Nothoscordum bivalve* and *Scirpus koilolepis* were dominant.

Fifteen additional species were recorded in April, seven annuals, five perennials, and three that can be biennial, annual, or perennial. Among the 15 were three Compositae, one Gramineae, and one Leguminosae. *Hedyotis crassifolia* and *Plantago virginica* were dominant.

The greatest number of new species, 43, was added in May. Twelve of these were in the family Gramineae, eight in the Compositae, and one in the Leguminosae. About half were perennials. The May additions accounted for nearly 41% of all herbaceous species on the area. Dominant species were *Oxalis dillenii*, *Gnaphalium purpureum*, and *Scleria oligantha*.

Twelve more species were recorded in June and 10 in August. Dominant in June were *Acalypha virginica*, *Cassia fasciculata*, and *Chasmanthium sessiliflorum*. In August, *Conyza canadensis*, *Croton capitatus*, *Galactia volubilis*, and *Lechea mucronata* were dominant. Fifty-nine percent of the species appearing in these two months were perennials. About half were Compositae or Gramineae, and 23% were Leguminosae.

In September, 17 species, all in the Compositae, Gramineae, and Leguminosae families, were added. Two-thirds were perennial. Dominant species were *Ambrosia artemisiifolia*, *Aristida virgata*, *Panicum brachyanthum*, and *Desmodium sessilifolium*.

The four new species in the October tally were all perennials in the Compositae or Gramineae. Dominant species were *Andropogon virginicus*, *Eupatorium capillifolium*, and *E. compositifolium*.

Woody Plant Species

The 56 woody species found on the area represented 27 families. Most were in the Fagaceae (6), Liliaceae (5), Rosaceae (5), and Vitaceae (4) families (table 2). Three non-native species were recorded: *Campsis radicans* from the n United States, *Robinia pseudoacacia* e Appalachians and Ozarks, and *Lonicera japonica* from Asia. *Lonicera japonica* and *Robinia pseudoacacia* were more important in the woods than in the open. *Campsis radicans* was found only in the woods.

Unlike the herbaceous plants, the majority of the woody plants (76.8%) occurred both in the open and in the woods. All the dominant species were found in both locations. *Rhus toxicodendron*, *Rubus* spp., and *Rhus copallina* had the highest importance values. Prevalent but less common were *Smilax bona-nox*, *Parthenocissus quinquefolia*, *Sassafras albidum*, and *Ampelopsis arborea*.

Trees in the overstory of the woods were mainly *Pinus taeda* and *P. echinata*, with an occasional *Quercus stellata*, *Q. falcata*, *Nyssa sylvatica*, and *Liquidambar styraciflua*. The understory species *Gelsemium sempervirens*, *Lonicera japonica*, and *Rhus toxicodendron* were more important in the woods than in the open, though they were recorded in both places.

Distribution of woody plants was limited somewhat by soils. Thirty-three woody species occurred on all soils. *Fraxinus americana*, *Maclura pomifera*, *Prunus umbellata*, and *Quercus alba* were found only on the Kalmia soil of the slope. *Acer rubrum*, *Carya texana*, *Chionanthus virginica*, *Forestiera ligustrina*, *Morus rubra*, *Quercus phellos*, and *Vitis aestivalis* grew on both Kalmia and Caddo soils. *Cephalanthus occidentalis*, *Smilax smallii*, and *Quercus primus* were found only on Boswell soil. Moisture and lack of previous cultivation are possible explanations for some species' affinity for particular soils.

LITERATURE CITED

Correll, D. C., and Johnston, M. C.
1970. Manual of the vascular plants of Texas. 1881 p. Texas Res. Found.

Daubenmire, R. F.
1968. Plant communities: a textbook of plant synecology. 300 p. Harper & Row, New York.

Schuster, J. L.
1967. The relation of understory vegetation to cutting treatments and habitat factors in an east Texas pine-hardwood type. Southwest. Nat. 12: 339-364.

Sullivan, J. R., and Nixon, E. S.
1971. A vegetational analysis of an area in Nacogdoches County, Texas. Tex. J. Sci. 23: 67-79.

Table 2.—*Importance values of woody plant species recorded on the experimental area*

Plant family and species	Importance value	
	Open	Woods
Fagaceae		
Quercus alba L.	1.5	0.5
Quercus falcata Michx.	7.5	9.3
Quercus nigra L.	4.2	6.7
Quercus phellos L.	.5	.7
Quercus prinus L.	.3	.2
Quercus stellata Wang.	2.1	2.7
Liliaceae		
Smilax bona-nox L.	11.1	12.9
Smilax glauca Walt.	7.6	6.1
Smilax laurifolia L.	1.1	3.7
Smilax rotundifolia L.	6.4	6.3
Smilax smallii Morong.	.2	...
Rosaceae		
Crataegus marshallii Eggl.	.2	...
Prunus serotina Ehrh.	.5	1.9
Prunus umbellata Ell.	...	.2
Prunus spp.	2.6	...
Rubus spp.	22.2	4.8
Vitaceae		
Ampelopsis arborea (L.) Koehne	10.0	6.9
Parthenocissus quinquefolia (L.) Planch.	10.4	9.5
Vitis aestivalis Michx.	.5	...
Vitis rotundifolia Michx.	1.6	1.9
Anacardiaceae		
Rhus copallina L.	17.8	5.2
Rhus glabra L.	1.2	1.0
Rhus toxicodendron L.	29.2	37.7
Oleaceae		
Chionanthus virginica L.	1.4	.2
Forestiera ligustrina (Michx.) Poir.	.7	1.1
Fraxinus americana L.	...	.2
Aquifoliaceae		
Ilex opaca Ait.	.2	...
Ilex vomitoria Ait.	1.5	1.7
Bignoniaceae		
Bignonia capreolata L.	2.5	3.5
Campsis radicans (L.) Seem.	...	3.4
Caprifoliaceae		
Lonicera japonica Thunb.	1.8	7.9
Viburnum rufidulum Raf.	1.8	2.9
Cornaceae		
Cornus florida L.	1.6	1.9
Nyssa sylvatica Marsh. var. *sylvatica*	1.2	1.3
Juglandaceae		
Carya texana Buckl.	0.7	1.6
Carya tomentosa Nutt.	.2	.5
Moraceae		
Maclura pomifera (Raf.) Schneid.	...	.5
Morus rubra L.	1.0	.2
Passifloraceae		
Passiflora incarnata L.	1.5	...
Passiflora lutea L.	.5	...
Pinaceae		
Pinus echinata Mill.	.8	3.9
Pinus taeda L.	5.3	1.4
Ulmaceae		
Celtis laevigata Willd.	.8	2.5
Ulmus alata Michx.	3.1	1.6
Aceraceae		
Acer rubrum L.	.5	.8
Apocynaceae		
Trachelospermum difforme (Walt.) Gray	.3	.7
Compositae		
Baccharis halimifolia L.	.2	...
Ebenaceae		
Diospyros virginiana L.	2.6	2.1
Hamamelidaceae		
Liquidambar styraciflua L.	6.3	5.5
Hypericaceae		
Ascyrum hypericoides L.	2.3	.5
Lauraceae		
Sassafras albidum (Nutt.) Nees.	9.8	11.9
Leguminosae		
Robinia pseudoacacia L.	1.5	5.5
Loganiaceae		
Gelsemium sempervirens (L.) Jaume St.-Hil.	2.4	9.7
Rhamnaceae		
Berchemia scandens (Hill) K. Koch	5.4	6.6
Rubiaceae		
Cephalanthus occidentalis L.	.2	...
Verbenaceae		
Callicarpa americana L.	3.6	2.2

SOUTHERN FOREST EXPERIMENT STATION

1974

U.S. FOREST SERVICE RESEARCH NOTE

SO-174

Forest Service, U.S. Dept. of Agriculture

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TUBE LENGTHS, SITE TREATMENTS, AND SEEDLING AGES AFFECT SURVIVAL AND GROWTH OF CONTAINERIZED SOUTHERN PINES

James P. Barnett[1]

SOUTHERN FOREST EXPERIMENT STATION

Survival and growth from midsummer plantings of containerized longleaf, slash, and loblolly pine seedlings varied greatly by soil type, site preparation, seedling age, and tube size. Summer planting schedules should be flexible, so as to permit waiting for good soil moisture conditions.

Additional keywords: *Pinus taeda*, *P. elliottii*, *P. palustris*, tubelings.

Barerooted southern pine nursery stock is usually planted during 3- to 4-month period in winter or early spring. The seedlings, which are dormant when planted, then have several months to regenerate their root systems before the onset of hot, dry weather. Containerization offers an opportunity to extend the planting season greatly, since the roots remain intact in the medium in which they first developed.

In the study reported here, tubelings of longleaf (*Pinus palustris* Mill.), slash (*P. elliottii* var. *elliottii* Engelm.), and loblolly (*P. taeda* L.) pine were planted during midsummer on a Ruston sandy loam soil. The object was to learn if tube length, seedling age, and method of site preparation would affect survival and growth under severe conditions of heat and drought. In a supplemental study, 2-month-old loblolly pine tubelings were also planted on a heavier Beauregard soil so that a measure of site effects could be obtained.

METHODS

The treatments tested in the main study were 4-, 6-, and 8-inch tube lengths, 1- and 2-month-old seedlings, and prepared and unprepared sites. On Beauregard soil the treatments were the same, except that only 2-month-old loblolly pine was planted.

Site preparation was completed about 2 months prior to planting; it consisted of solid disking. The unprepared sites had a light rough of grasses that had developed after a burn.

Tube material was bleached kraft paper (uncoated milk carton stock) furnished and formed into 7/8-inch square tubes by the International Paper Company. The tubes were filled with a 1:1:1 mixture of topsoil, peat, and sand. No nutrients were applied.

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Seeds were germinated in the tubes in a greenhouse where the maximum temperature was about 80° F. Those of loblolly pine were stratified for 30 days prior to use. The 1 to 2 weeks required for germination was not included in seedling age. To keep roots from coming out of the open-ended tubes, all stock was grown on copper screen. Sowing dates were arranged so that seedlings for all treatments were ready to plant on July 6, 1971.

Seedings were set in square holes made with a specially fabricated hand tool. Spacing was 2 by 4 feet. Soil moisture was adequate at planting, but no rain fell in the 2 weeks following.

At 18 months after planting, seedlings were measured to the nearest 0.1 foot of height for loblolly and slash pine, and to the nearest 1/16 inch of rootcollar diameter for longleaf pine. Although survival was also measured at 6 months, only data at 18 months are presented here. Changes between the two dates were minor.

RESULTS

Survival

While survival was generally low, there were marked differences among species and treatments (table 1). Longleaf seedlings generally survived the best and loblolly seedlings the poorest. There also were interactions between species and treatments. In longleaf pine, for example, survival increased significantly (0.05 level) with increases in tube length, with increasing seedling age, and with disking of the site; but in slash pine only seedling age significantly influenced survival.

For the average of the two age classes, survival of longleaf was 22, 31, and 44 percent for 4-, 6-, and 8-inch tubes. Two-month-old seedlings survived more than twice as well as 1-month seedlings, the averages being 45 and 19 percent. Site preparation aided longleaf tubelings of both age classes, survival averaging 43 percent on disked sites and 21 percent in the light rough.

Table 1.—*Average survival and size of containerized seedlings 18 months after planting*

Tube length (inches)	Seedling age	Site preparation	Survival				Size[1]			
					Loblolly				Loblolly	
			Longleaf	Slash	Dry site	Wet site	Longleaf	Slash	Dry site	Wet site
	Months		— — — — *Percent* — — — —				*Inch*		— — — — *Feet* — — — —	
4	1	Rough	3	17	10	...	0.19	0.94	0.72	...
		Disked	15	23	36	...	.30	1.08	.66	...
		Avg.	9	20	23	...	.23	1.00	.69	...
	2	Rough	18	29	19	45	.19	1.19	.42	0.37
		Disked	51	36	19	46	.28	1.14	.74	.88
		Avg.	34	32	19	46	.23	1.16	.58	.62
6	1	Rough	11	15	31	...	.17	1.25	.59	...
		Disked	30	20	14	...	.30	1.33	.82	...
		Avg.	20	17	22	...	.24	1.29	.70	...
	2	Rough	31	29	17	36	.19	.92	.48	.38
		Disked	53	22	10	32	.29	1.16	.84	.70
		Avg.	42	26	14	34	.24	1.04	.66	.54
8	1	Rough	14	13	19	...	.18	1.03	.52	...
		Disked	41	25	35	...	.34	1.11	.96	...
		Avg.	28	19	27	...	.26	1.07	.74	...
	2	Rough	51	52	26	50	.22	1.11	.66	.33
		Disked	68	41	7	20	.38	1.21	.62	.61
		Avg.	60	46	16	35	.30	1.16	.64	.47

[1] Rootcollar diameter in inches for longleaf; height in feet for slash and loblolly pine.

The best combination of treatments for longleaf —giving 68 percent survival—was to plant 2-month-old seedlings in 8-inch tubes on disked sites.

In slash pine, where only seedling age was significant, 1-month-old seedlings averaged 19 percent survival, as compared to 35 percent for those 2 months old. Survival in 4-, 6-, and 8-inch tubes averaged 26, 22, and 32 percent, respectively, and the disked site was only 2 percentage points better than the rough.

Loblolly survival was slightly, but not consistently, lower than for slash pine. Age was the major factor affecting survival, but, in contrast to slash pine, 1-month-old seedlings lived best—24 versus 16 percent. The better survival of the younger seedlings occurred on disked sites; survival of the two age classes was nearly equal in the rough.

The 2-month loblolly seedlings fared better on the Beauregard soil than on the Ruston. Overall survival was 38 percent on the wet, heavy soil and 16 percent on the sand. When data from the two soils were combined, 32 percent survived in the rough as contrasted to 22 percent on disked areas.

On both soils, survival decreased significantly with increases in tube length on disked sites, while there was no consistent trend with tube length in the rough. Averages for 4-, 6-, and 8-inch tubes were 32, 21, and 14 percent on disked soil and 32, 26, and 38 percent in the rough.

Growth

Growth also varied by species. For longleaf, disking improved growth substantially (table 1), and at 18 months seedlings were almost 70 percent greater in caliper than those in the rough. Tube length had little influence.

Growth of slash seedlings was only slightly affected by any of the treatments, though disking increased heights by about 10 percent. Overall height after 18 months was 1.1 feet.

Loblolly grew less than slash, averaging 0.7 foot. Site preparation significantly affected growth; seedlings on disked sites averaged 0.77 foot as compared to 0.57 for those in the rough. There were no differences between the dry and moist soils. For all sites combined, growth averaged 0.73 foot on disked soil and 0.44 foot in the rough. As with survival, increases in tube length were beneficial in the rough and detrimental on disked sites.

DISCUSSION

Responses in survival and growth varied greatly by species. Longleaf pine had the best overall survival, probably because it develops a better root system than the other species while growing in tubes in the greenhouse. Disked sites were definitely superior for longleaf seedlings.

Age was the only variable that significantly affected slash pine survival—the 2-month seedlings performed much better than those only 1 month old. In contrast—and for reasons unknown—1-month loblolly seedlings survived better than those 2 months old, particularly on disked sites. Survival and growth of 2-month seedlings decreased with increases in tube length on disked sites and increased with length in the rough. These greater differences in response of loblolly pine probably reflect the sensitivity of young seedlings of this species to environmental conditions. Experience has shown that both longleaf and slash seedlings are more hardy. Long tubes probably improved survival and growth in dry soils and on unprepared sites for the reason that roots could contact moisture more readily at greater depths. When moisture was adequate near the surface, short tubes were superior because roots concentrated at the bottom could rapidly extend into surrounding soil.

The rather poor growth of all three species probably is due mainly to dry weather after planting, but it may be partially attributed to the kraft paper used for the tubes. Although both 1- and 2-month seedlings extended their roots to the bottom of the tubes during the greenhouse phase, other studies have shown that lateral roots develop slowly and height growth lags until the paper is completely decomposed. Addition of nutrients during the greenhouse propagation period would hasten paper decomposition and greatly increase growth after outplanting.

Had rains occurred soon after planting, survival of all species would have been higher. Summer planting will probably require a schedule flexible enough to permit waiting for rains.

Finally, this study should not be taken as indicating the best that can be expected in an extended planting season. It is likely that changes in type of container and rooting media, plus the addition of nutrients, will improve survival and growth considerably, even in dry midsummer conditions.

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1974

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GROWTH OF LONGLEAF PINE PLANTATIONS AFTER INITIAL THINNING

Richard E. Lohrey[1]

SOUTHERN FOREST EXPERIMENT STATION

Periodic annual volume growth after the first thinning (at age 25 years) increased with residual density, exceeding 2 cords per acre above 70 square feet of basal area. Diameter and volume growth of individual trees were related to stand density and initial d.b.h.

Additional keywords: *Pinus palustris* Mill., growth, thinning.

This note reports growth of planted longleaf pines during the first 5 years after initial thinning. The data are from two plantations near Jasper, Texas—one on the Angelina and one on the Sabine National Forest.

The sites, which formerly supported old-growth longleaf, are typical of large areas in the West Gulf Coastal Plain. Soils are sandy loams with A horizon varying from 10 to 20 inches deep and with sandy clay subsoils that retard internal drainage. Topography is rolling to hilly, slopes are 3 percent or more, and surface drainage is good.

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Trees were planted by the bar-slit method at 6- by 6-foot spacing. Initial survival was good in one stand but the other required replanting. Plots were established and thinnings were made at plantation ages 24 and 25 years, but the 1-year difference in age was disregarded when data were analyzed.

STUDY DESCRIPTION

Six residual densities plus an unthinned check treatment are being tested. Assigned densities range from 40 to 140 square feet of basal area per acre at 20-foot intervals. Each treatment is replicated six times in a completely randomized design. Plots are square and 0.67 acre in size. Measurements are confined to the central 0.25 acre, on which all trees are individually identified.

Thinning was from below. Some, but not all, submerchantable stems were cut along with merchantable trees. Plots for the 120- and 140-square-foot treatments had not reached their assigned densities and hence were not thinned.

D.b.h. of all trees 0.6 inch and larger was measured before thinning and again 5 years

later. Total height and height to succeeding 2-inch-diameter taper steps were measured on 12 sample trees per plot before and after each thinning. Volume in cubic feet of each sample tree was calculated by height accumulation (Grosenbaugh 1954). Volume on individual plots was computed by multiplying basal area by the volume/basal-area ratio for sample trees on the plot.

Mean total height of 10 or more well-spaced dominants and codominants on each plot was used to determine site index from 2 in Miscellaneous Publication 50 (U. S. Dep. Agric. 1929). Site indices averaged 83 feet and ranged from 75 to 90, with 70 percent between 80 and 87 feet.

Data from all plots, thinned and unthinned, were combined in regression analyses to screen many combinations of independent variables. Equations relating volume growth to basal area of merchantable trees were fitted. Merchantable volumes in cubic feet to a 4-inch top o.b. were converted to cords by a factor of 90 cubic feet per cord.

INITIAL STAND CONDITIONS

Before thinning, density in the two plantations averaged 582 trees with 112 square feet of basal area per acre. Stocking on individual plots ranged from 368 to 868 trees and 87 to 135 square feet of basal area per acre. A typical plot is shown in figure 1.

Merchantable volumes averaged 32 and 34 cords per acre in the 24- and 25-year-old stands, respectively. Volumes were directly related to basal area, ranging from 18 cords in plots with 87 square feet to 45 cords in those with 135 square feet per acre. No attempt was made to relate initial volumes to age or site index. Ranges for these variables were small and relationships found here would not apply elsewhere.

Mean diameter of all trees before thinning was 6.0 inches. On individual plots the average d.b.h. ranged from 5.0 to 6.7 inches. Most trees were in the 5-, 6-, and 7-inch classes with relatively few trees below 2 inches or above 8 inches. Approximately 75 percent were in merchantable size classes (3.6 inches d.b.h. or larger).

Table 1 shows diameter distributions in all plots before cutting and in four thinned treatments after cutting. Light thinnings left more trees than heavy thinnings in most diameter classes, including the largest ones. All treatments removed mostly small stems, but large trees were cut if they were diseased or defective. Heavy thinnings also removed large trees to improve spacing. Thus, mean diameter of the 100 largest trees per acre was reduced more by heavy than by light thinning:

Residual density	Mean d.b.h. 100 largest trees		
	Before cutting	After cutting	Change
Sq. ft.	*Inches*		
40	8.7	7.9	—0.8
60	8.9	8.3	— .6
80	8.9	8.4	— .6
100	8.8	8.6	— .2
Uncut	8.4	8.4	.0

RESULTS

Periodic Annual Growth

Periodic annual merchantable volume growth ranged from 117 to 205 cubic feet per acre in plots thinned to 40 and 100 square feet. Maximum volume increment was attained in un-

Table 1.—*Trees per acre by diameter class, age 25 years*

Thinning treatment	Diameter class—inches												Total in all classes
	1	2	3	4	5	6	7	8	9	10	11	≥12	
	Number												
All treatments[1]	15	52	61	70	84	98	94	64	27	11	4	2	582
100 sq. ft.[2]	3	15	36	60	79	93	79	66	27	11	1	1	471
80 sq. ft.[2]	0	1	7	18	48	84	72	59	24	7	1	...	321
60 sq. ft.[2]	2	7	7	12	27	44	60	46	21	9	3	...	238
40 sq. ft.[2]	0	1	2	2	11	31	42	42	13	2	1	1	148

[1] Before thinning.
[2] After thinning.

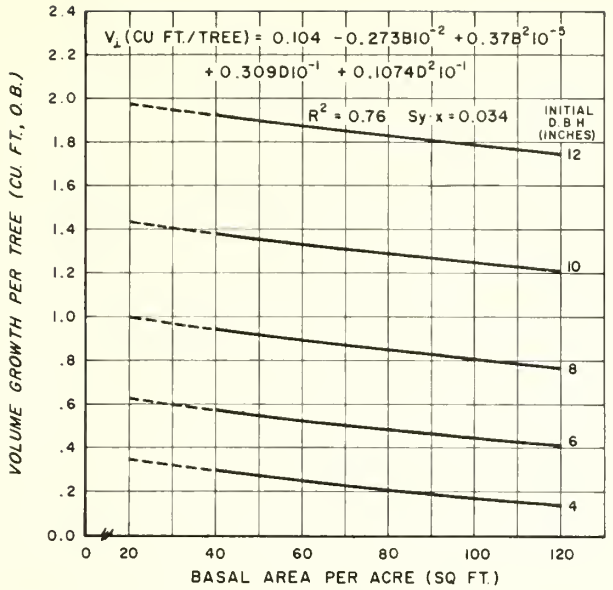

Figure 4.—*Periodic annual volume growth per tree in relation to stand density and initial diameter.*

The ratio between cubic-foot volume of all sample trees and their total basal area increased in all thinning treatments during the 5-year period. The changes were smaller at low than at high residual densities:

Density	*Increase in ratio*
40	3.60
60	3.74
80	4.51
100	4.63
110 (unthinned)	4.83

The difference in volume/basal-area ratio was partially responsible for proportionally less volume than diameter growth at low densities. After heavy thinnings, residual trees make faster diameter growth at breast height than farther up the stem (Larson 1963), and taper increases as a result.

DISCUSSION

Derr and Enghardt (1969) reported that longleaf pine yields at first thinning increased with initial stand density (in square feet of basal area per acre), and that periodic annual growth increased with residual density after thinning. They reported total cordwood yields per acre as follows:

Density	*Age 20*	*Age 30*
	— — *Cords* — —	
60	16.0	35.5
80	17.4	40.6
100	21.2	48.3

With allowance for the difference in age at initial thinning, these yields compare closely with those obtained in this study. The two studies were on similar sites.

A tree's diameter is important in determining its utility for pulpwood, veneer logs, saw logs, or poles. Ability to estimate growth rates of individual trees under various thinning regimes should be valuable for forest managers. The regressions on initial d.b.h. and stand density accounted for three-fourths of the variation in diameter and volume growth of individual trees in this study. Thus, it may be possible to predict growth from a few simple measurements. Data from wider ranges of age and site index need to be included, however, and the equations tested under various conditions.

LITERATURE CITED

Derr, H. J., and Enghardt, H. G.
1969. Growth in a young managed longleaf pine plantation. J. For. 67: 501-504.

Grosenbaugh, L. R.
1954. New tree-measurement concepts: height accumulation, giant tree, taper and shape. USDA For. Serv. South. For. Exp. Stn. Occas. Pap. 134, 32 p.

Larson, P. R.
1963. Stem form development of forest trees. For. Sci. Monogr. 5, 42 p.

U. S. Department of Agriculture.
1929. Volume, yield, and stand tables for second-growth southern pines. USDA Misc. Publ. 50, 202 p.

thinned plots, averaging 220 cubic feet (2.44 cords) where stand density was 110 square feet per acre. An equation relating periodic annual volume increment (Va) to stand basal area (B) accounted for 61 percent of the variation in volume growth (fig. 2).

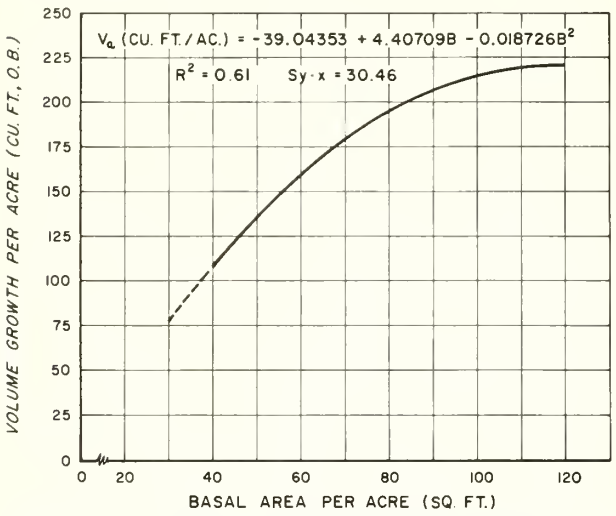

Figure 2.—*Annual merchantable volume growth per acre during the 5-year period after initial thinning.*

At low stocking levels, merchantable volume growth increased in direct proportion to basal area. At higher densities, growth leveled off but did not peak within the range tested.

Basal-area growth also increased rapidly at low densities and leveled off at higher ones. The equation relating periodic annual basal area growth (B.A.) to residual basal area per acre is:

$$\text{B.A. (sq.ft.)} = 1.4104 + 0.5345B \times 10^{-1} - 0.1935B^2 \times 10^{-3}$$

$R^2 = 0.75$, $Sy{\cdot}x = 0.35$

Estimated basal area growth in stands of various densities was as follows (all values in square feet per acre):

Density	*Growth*
40	3.24
60	3.92
80	4.45
100	4.82
120	5.04

Mean periodic annual diameter growth for all trees ranged from 0.13 inch in unthinned plots to 0.26 inch in those thinned to 40 square feet per acre. Growth of individual trees was faster at low than at high stocking levels, and large trees grew faster than small ones at all densities. An equation (fig. 3) was fitted to relate diameter growth (G) to initial d.b.h. (D) and stand basal area (B). Solution of the equation indicates that growth was 0.10 inch for 4-inch trees, 0.16 for 6-inch trees, and 0.21 for 8-inch trees where stand density was 80 square feet per acre. Thus, 8-inch trees grew twice as fast as 4-inch ones. The relationship was similar at other densities.

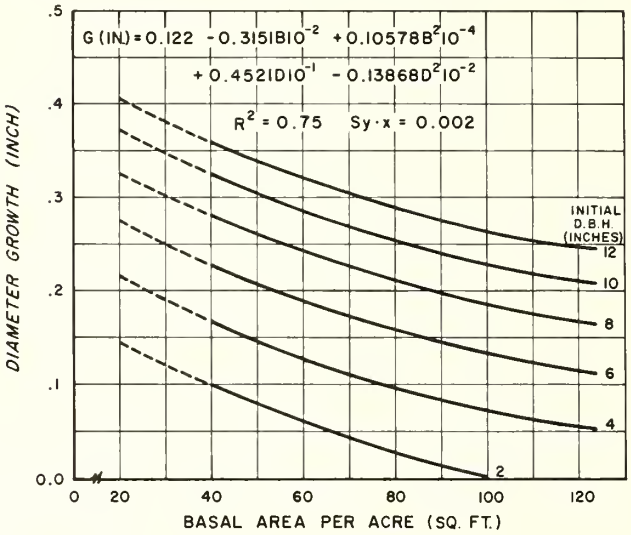

Figure 3.—*Periodic annual diameter growth in relation to stand density and initial diameter.*

Periodic annual volume growth of individual trees (Vi), determined from upper-stem measurements, was inversely related to basal area density and directly related to initial diameter (fig. 4). Tree diameter was the critical factor. Dense stocking reduced growth per tree for all diameter classes, but 6-inch trees grew more at 120 square feet than 4-inch trees did at 40 square feet. Similarly, 8-inch trees usually produced about four times more volume than 4-inch trees and almost twice as much as 6-inch ones.

Other variables that were believed to influence tree growth were screened to see if they improved the relationship. These variables included crown class[2], total height, percent of total height in live crown, initial basal area, initial volume and the squares and reciprocals of these factors. None improved the fit appreciably. It was concluded that these variables, most of which are correlated with diameter in some way, are unimportant after the influences of stand density and diameter have been considered.

[2] Crown classes were assigned numerical codes: dominants = 1, codominants = 2, intermediates = 3, and overtopped trees = 4.

Figure 1.—*A typical longleaf pine plantation before and after thinning to 60 square feet of basal area per acre at age 24 years.*